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CONCEPTUAL DESIGN STUDIES OF 1985 COMMERCIAL VTOL TRANSPORTS THAT UTILIZE ROTORS

VOLUME II

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ABSTRACT

This report is the second of two documents which present the results of conceptual design studies of tilt rotor and tandem helicopter aircraft for a 200 nautical mile commercial short haul transport mission. The primary results of this study are reported in Volume I. This volume presents the trade study data used in selecting the design point aircraft and technology details necessary to support the design conclusions.

The design studies reported herein were performed by the Boeing Vertol Company for the National Aeronautics and Space Administration under NASA Contract NAS2-8048.

FOREWORD

This report was prepared by the Boeing Vertol Company for the National Aeronautics and Space Administration, Ames Research Center, under NASA Contract NAS2-8048.

Mr. D. Giulianetti and Mr. K. H. Edenborough were technical monitors for this work.

The Boeing Vertol program manager was J. P. Magee and project engineer was R. D. Clark.

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1.0 INTRODUCTION

This report presents results of a conceptual design study of VTOL commercial transports in the 1985 time frame. Two configurations have been studied - the tandem rotor helicopter and the tilt rotor. These aircraft are designed to carry 100 passengers over a 200 nautical mile mission.

The primary results of this study are reported in Volume I. This document is intended to serve as a backup document and contains the trend studies which were performed to define the design point aircraft and also technical data to provide background and verification of design details.

The objectives in performing these studies were twofold. The primary objective was to define two aircraft, one of each configuration which minimized direct operating costs for the short haul mission within realistic technology constraints. The design characteristics of the aircraft are to be used in a larger study of short haul transportation systems to be done by NASA.

The secondary objective was to identify the aircraft size, weight, performance, costs and noise levels in order that the configurations can be compared with other forms of transportation available to the short haul traveller.

The trade studies which were performed to allow design point aircraft selection are included in this volume in Section 2. Section 3 provides supporting data in each of the technology disciplines pertinent to the preliminary designs and finally

for completeness the study guidelines are included in Section 4.

2.0 SIZING AND TREND STUDY DATA

The process of selecting a vehicle for a given mission requires several parametric trade studies to evaluate the impact of the design parameters on the vehicle weight, performance and costs. The tandem helicopters were sized using an automated iterative procedure HESCOMP. This program was developed by Boeing Vertol for NASA under NASA Contract NAS2-6107. The tilt rotor aircraft were sized using VASCOMP which is a similar program to HESCOMP, but specifically designed to handle V/STOL aircraft. These programs are documented in References 1and 2.

At the start of the development of a new aircraft, some initial estimates of the design parameters must be made based on simple preliminary calculations and experience. These data form the basis for the first trade studies from which the best values of each of the important parameters can be selected. As the trade study progresses the details of the vehicle become better defined and the final trade studies allow the selection of the aircraft.

In this series of trade studies this exercise was pursued for the baseline aircraft to define the aircraft with minimum direct operating cost at 200 nautical mile range. Following definition of the baseline aircraft,perturbations in the design parameters were made and the impact on the 500-foot sideline hover noise levels determined. From these studies the most effective means of varying the takeoff noise levels

were defined and further trade studies performed to allow the ± 5 PNdB aircraft to be selected for each configuration. The tradeoff data derived from these studies for both tandem helicopter and tilt rotor aircraft are presented in the following sections.

2.1 TANDEM ROTOR HELICOPTER - SIZING TRADES

The initial estimates of design data for the tandem rotor helicopter were that it would have three engines, have a rotor tipspeed of 750 feet per second, a gap to stagger ratio of 0.09, and would cruise at hover tipspeed. This initial aircraft was set up to size the rotor solidity for the C_T/σ limit shown in Section 3. The first sizing data was performed for three different sizes of aircraft (50, 75 and 100 passengers) and also for aircraft disc loadings between 6 and 10 pounds per square foot. The data from these aircraft parametrics are shown in Figures 2.1a to 2.1d. The results show that the minimum weight aircraft occurs at a disc loading of 9 pounds per square foot, and that cruise speed is not very sensitive to disc loading.

Since the fuselage length was held constant for a fixed number of passengers the overlap of the rotors varies with disc loading and rotor diameter as shown in Figures 2.1a and 2.1b. The installed power and mission fuel increase with disc loading. The equivalent drag area is insensitive to disc loading, but exhibits a minimum at W/A = 9 pounds per square foot.

The general size of the 100 passenger aircraft is well within the current experience range for tandem helicopters and resulted in the selection of a 100 passenger vehicle. The 100 passenger aircraft was next sized with a gap to stagger ratio of .09, three engines with the cruise performed at 3,000 feet as shown in Figures 2.2a to 2.2c.

Similar sizing data were generated at 6,500 feet altitude (Figures 2.3a to 2.3c) and at 10,000 feet altitude (Figures 2.4a to 2.4c).

The best cruise altitude for the tandem helicopter is at sea level however, an operational altitude of 5,000 feet was selected since sea level operation is not practical and potential terminals could be as high as 5,000 feet (e.g., Denver). Another consideration in selecting 5,000 feet as the operational altitude was to allow sufficient air space for entry into autorotation should this become necessary.

Figures 2.5a to 2.5d show trade study data for various tip-speed ratios between hover and cruise flight at a disc loading of 9 pounds per square foot. Although reducing the rotor RPM in cruise provides a cruise speed increase there is a large penalty in aircraft weight due to increasing rotor solidity, and rotor system weight. It was decided at this point to fly the mission at constant RPM.

The initial estimates of weight constants and drag trends estimation for the initial studies were reworked to provide updated input data which more closely reflected the size,

weight and type of the aircraft and component parts. Using this updated information the initial trade studies for the effect of number of passengers, disc loading and tipspeed were rerun at 5,000 feet altitude. These data are presented in Figures 2.6a to 2.6m, and include data for the 500-foot sideline noise and direct operating cost in cents per seat mile in Figures 2.6e, 2.6f and 2.7d. This data confirms that a disc loading of 9 pounds per square foot coincides with minimum direct operating cost at a tipspeed of 750 feet per second and also that the largest aircraft (100 passengers) is the most cost effective in terms of direct operating cost.

At this point in the study a disc loading of 9 pounds per square foot was fixed for a 100 passenger aircraft. The next area of investigation was to determine the impact of increased transmission rating over the guideline criterion. This was done to increase cruise speed and obtain a lower direct operating cost. The trend data resulting from these computations is shown in Figures 2.8a to 2.8f.

Figure 2.8a shows the variation of gross weight and dollars per air mile with hover tipspeed and transmission torque ratio. The transmission torque ratio is defined as torque capability over the torque required in hover, all engines operating.

The selected vehicle was at 725 feet per second hover tipspeed and a torque ratio of 1.04. A further reduction of tipspeed

to 700 feet per second would provide a slightly lower direct operating cost, however, the increase in gross weight and therefore initial cost would be large.

The geometric and performance parameters for these trend aircraft are displayed in Figures 2.8b through 2.8f.

This discontinuity in the cruise speed plot (Figure 2.8d) occurs at a point where the transmission rating matches the power available, all engines operating, in cruise at design cruise altitude and velocity.

The aircraft selected from the trend data weighed 65,100 pounds. The next step in the refinement process was to provide detail checks on all the input parameters, for example drag, weight trends, etc.

Some further refinements included the elimination of overlap which necessitated increased aft pylon sweep. Additional entrance/egress capabilities were provided to allow emergency egress capability compatible with FAR 29.

The parametrics defined by the trend study and the updated weights, drag and geometric variables were then used to size the final design point aircraft which resulted in a design gross weight of 67,175 pounds as shown in Volume I, Table 2.2 and also Section 3 of this document.

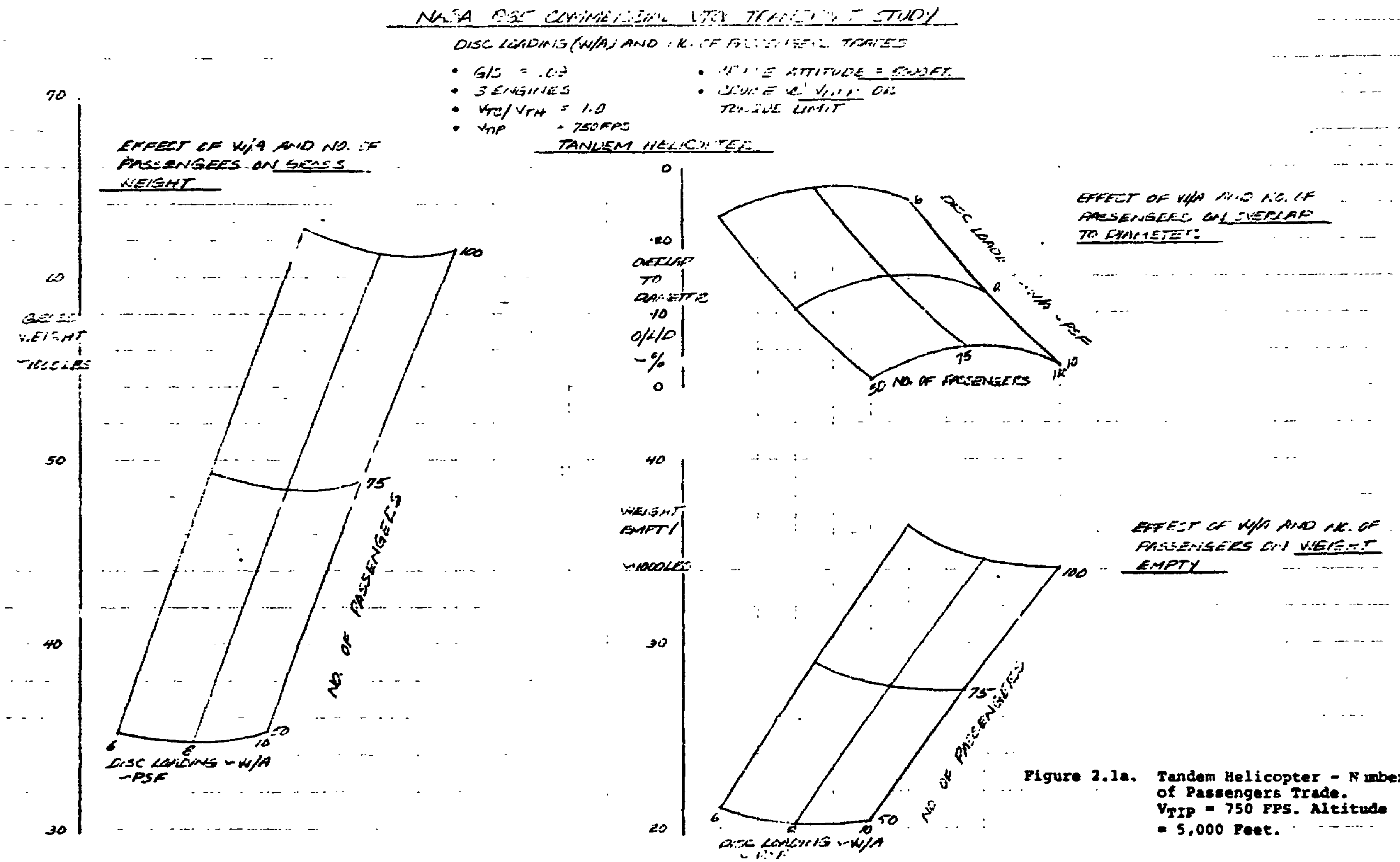

Figure 2.1a. Tandem Helicopter - N mber of Passengers Trade. V_{TIP} = 750 FPS. Altitude = 5,000 Feet.

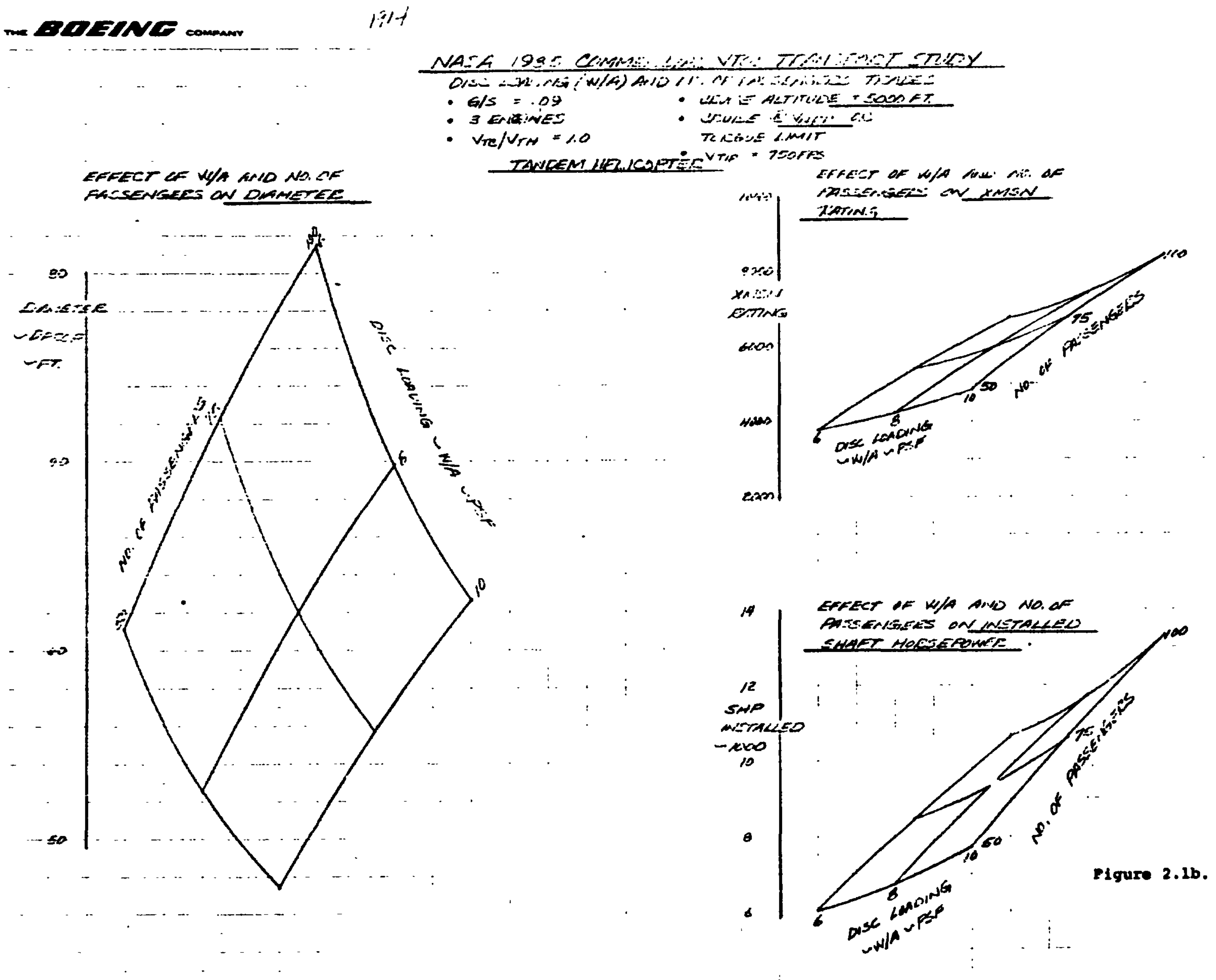

Figure 2.1b. Tandem Helicopter - Number of Passengers Trade. V_{TIP} = 750 FPS. Altitude = 5,000 Feet.

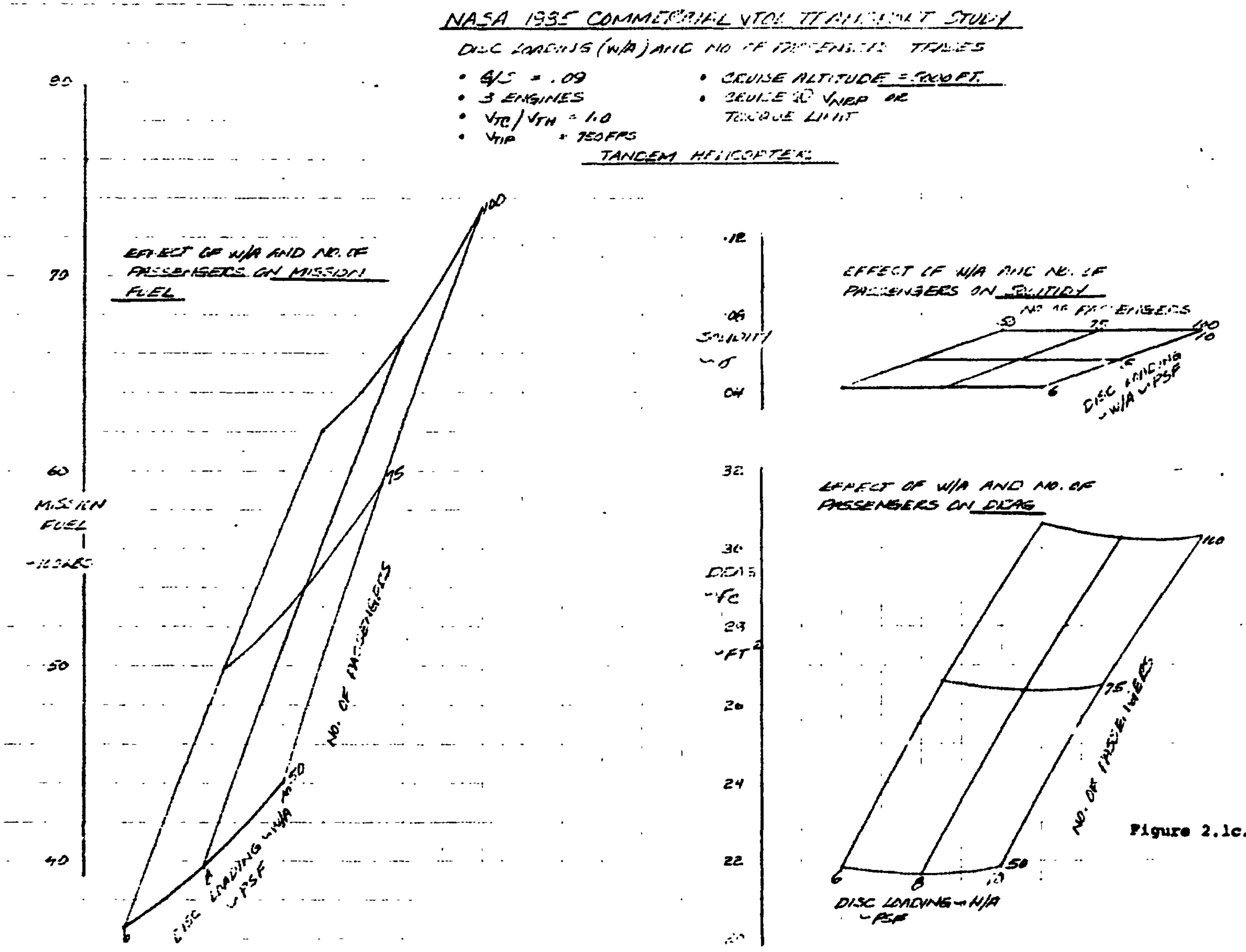

Figure 2.1c. Tandem Helicopter - Number of Passengers Trade. V_{TIP} = 750 FPS. Altitude = 5,000 Feet.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND NO. OF PASSENGERS TRADES

- G/S = .09
- 3 ENGINES
- V_{TC}/V_{TH} = 1.0
- V_{TIP} = 750FPS
- CRUISE ALTITUDE = 5000 FT.
- CRUISE @ V_{NEP} OR TORQUE LIMIT

TANDEM HELICOPTER

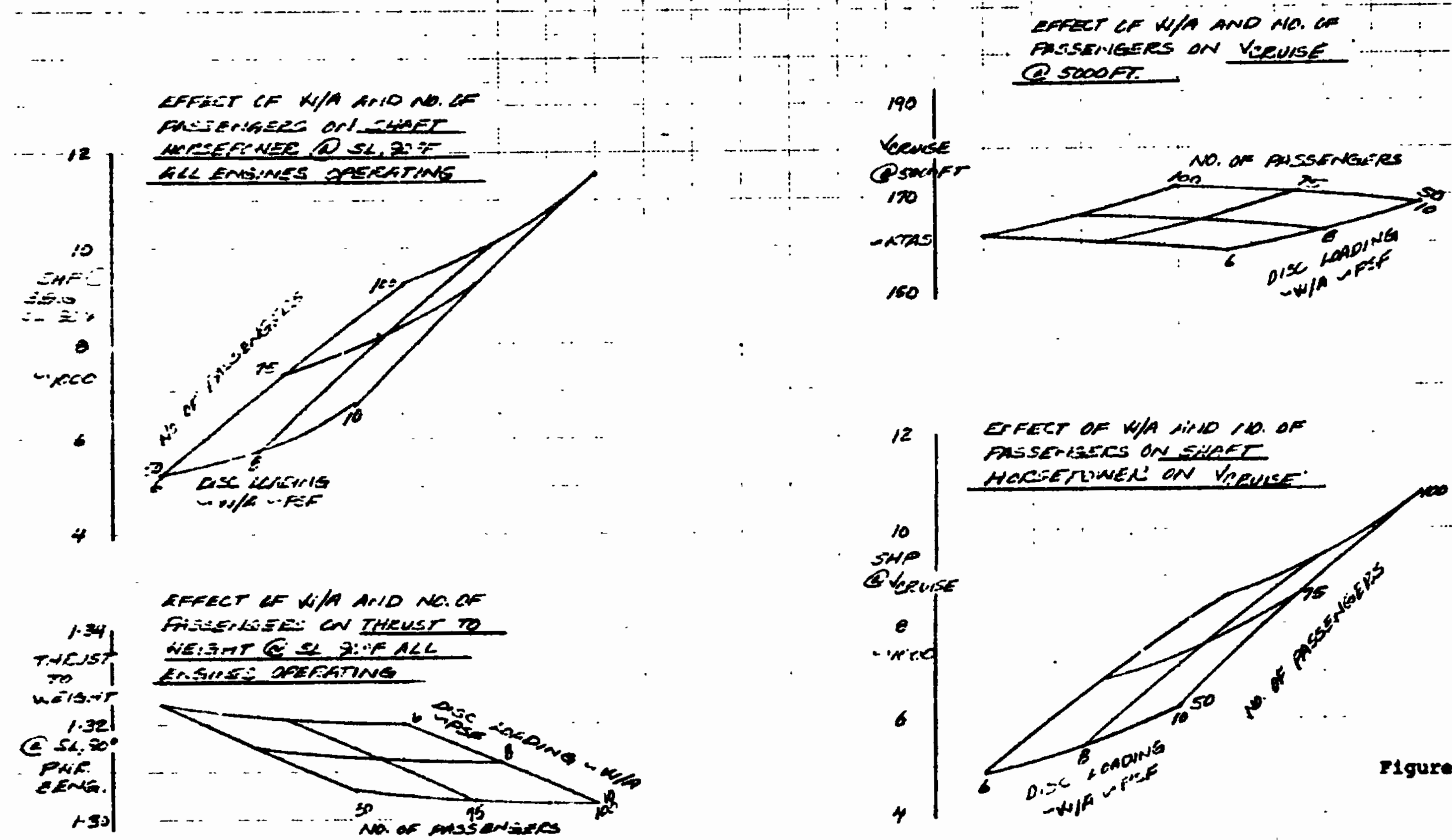

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Figure 2.1d. Tandem Helicopter - Number of Passengers Trade. V_{TIP} = 750 FPS. Altitude = 5,000 Feet.

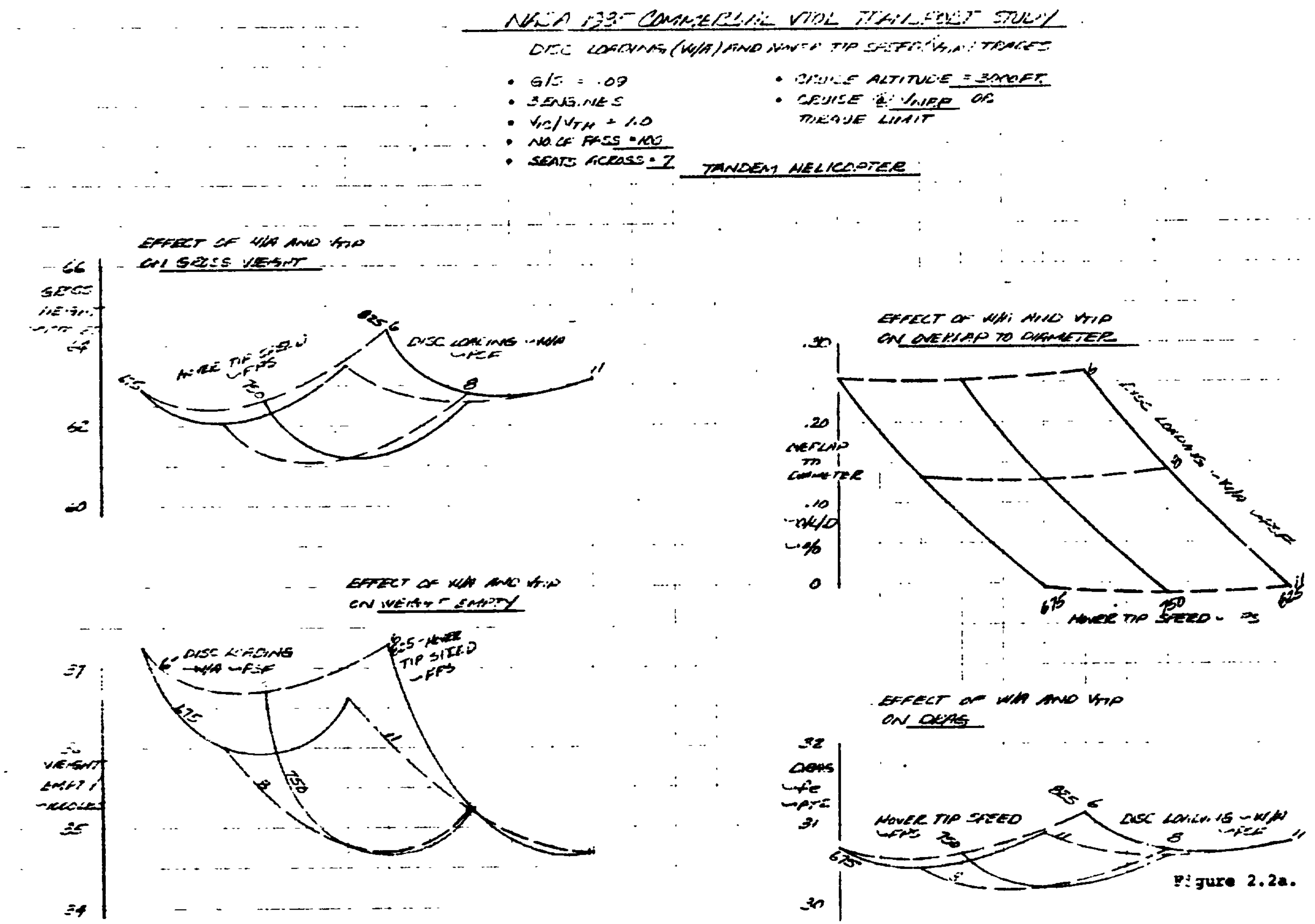

Figure 2.2a. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 3,000 Feet.

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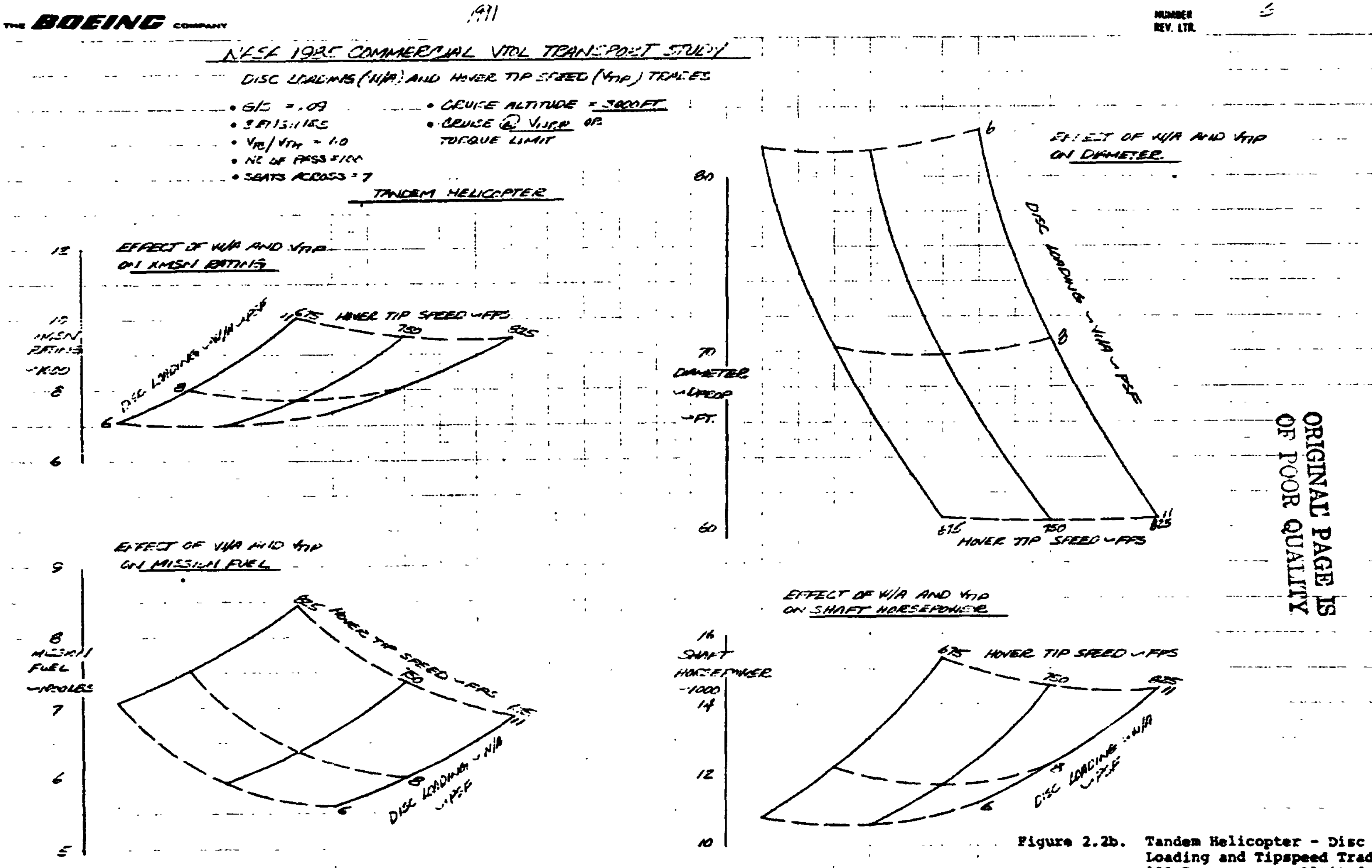

Figure 2.2b. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 3,000 Feet.

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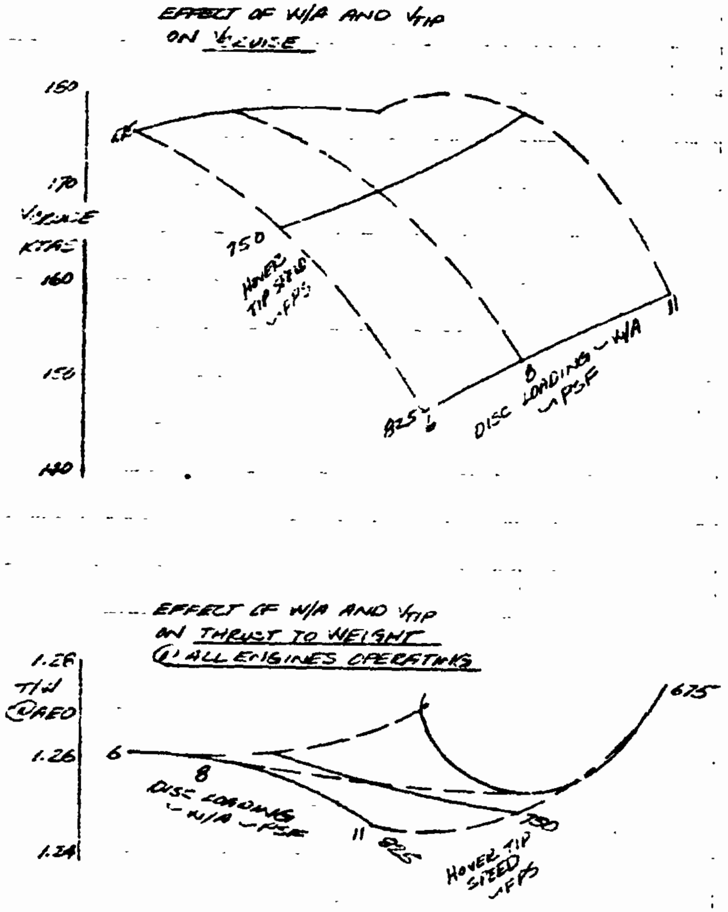
DISC LOADING (W/A) AND HOVER TIP SPEED (V_{TIP}) TRADES

- σ/S = .09
- 3 ENGINES
- V_{10}/V_{TH} = 1.0
- NO OF PASS = 100
- SEATS ABREAST = 7

CRUISE ALTITUDE = 3000 FT
CRUISE @ V_{NIRP} OR
TORQUE LIMIT

TANDEM HELICOPTER



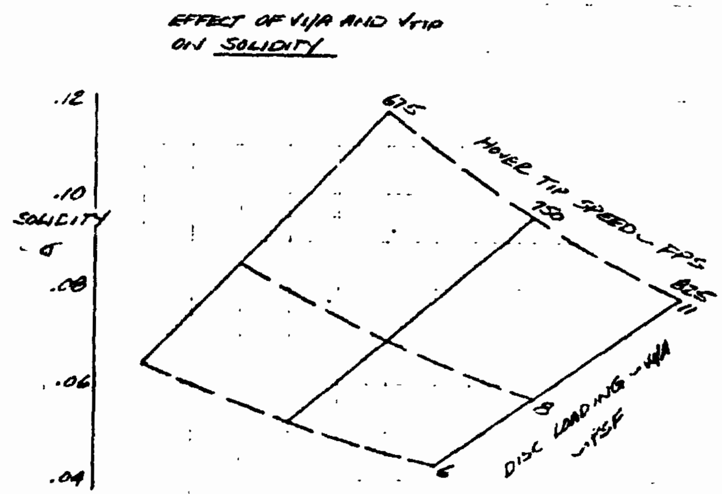


Figure 2.2c. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 3,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND HOVER TIP SPEED (V_{TIP}) TRADES

G/S = .09
3 ENGINES
V_{TC}/V_{TH} = 1.0
NO OF PASS = 100
SEATS ACROSS = 7

CRUISE ALTITUDE = 6500 FT
CRUISE @ V_{MRP} OR
TORQUE LIMIT

TANDEM HELICOPTER

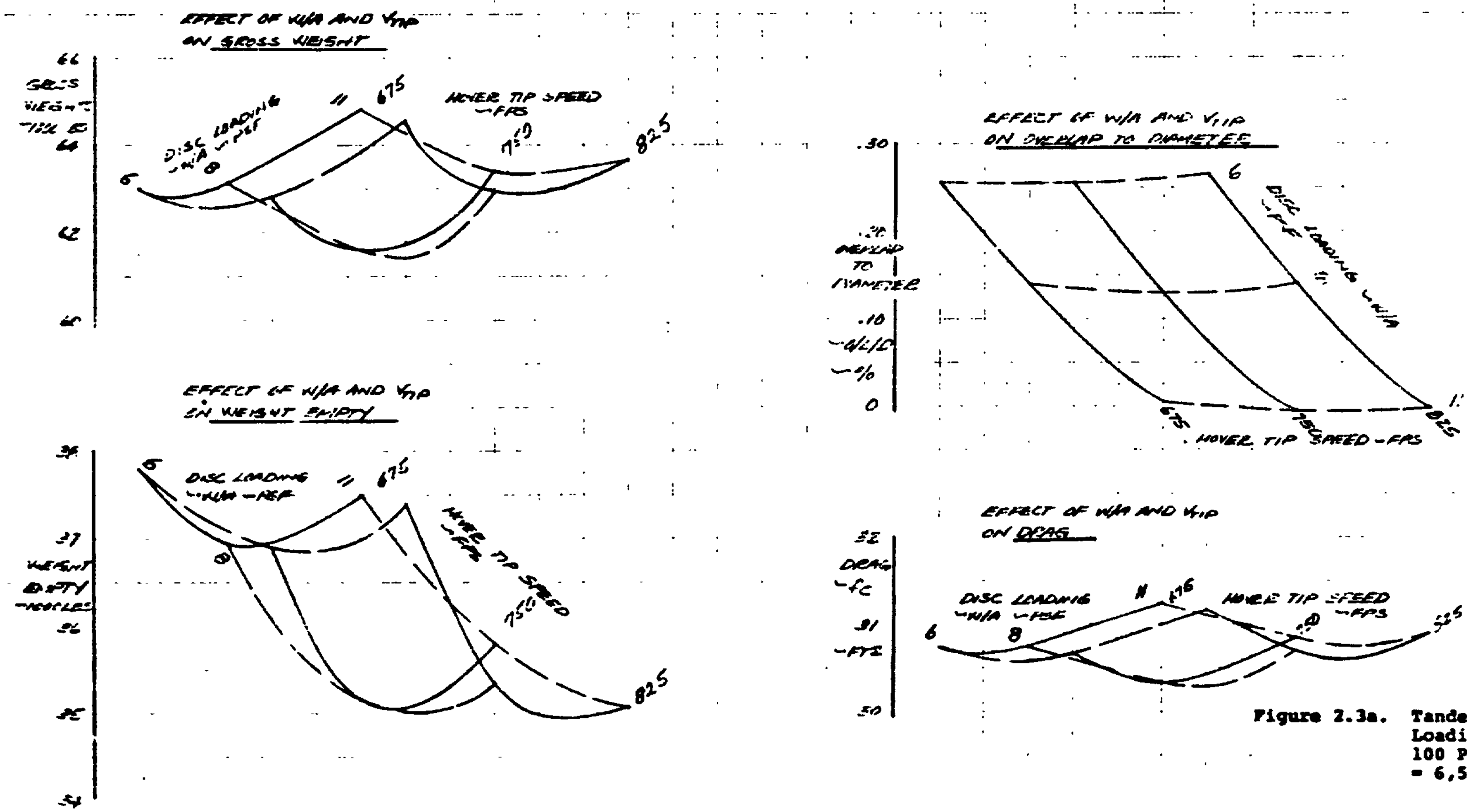


Figure 2.3a. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 6,500 Feet.

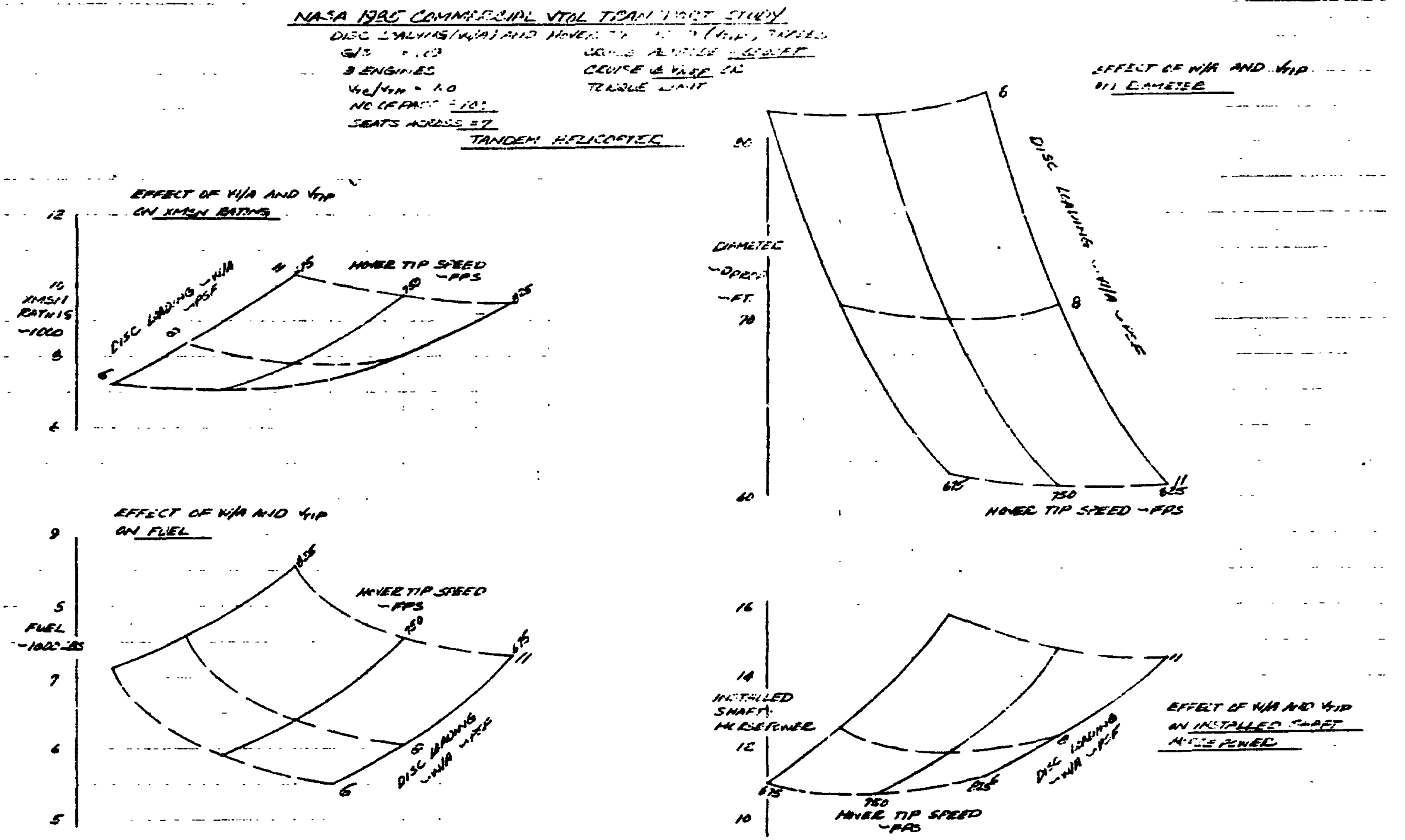


Figure 2.3b. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 6,500 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

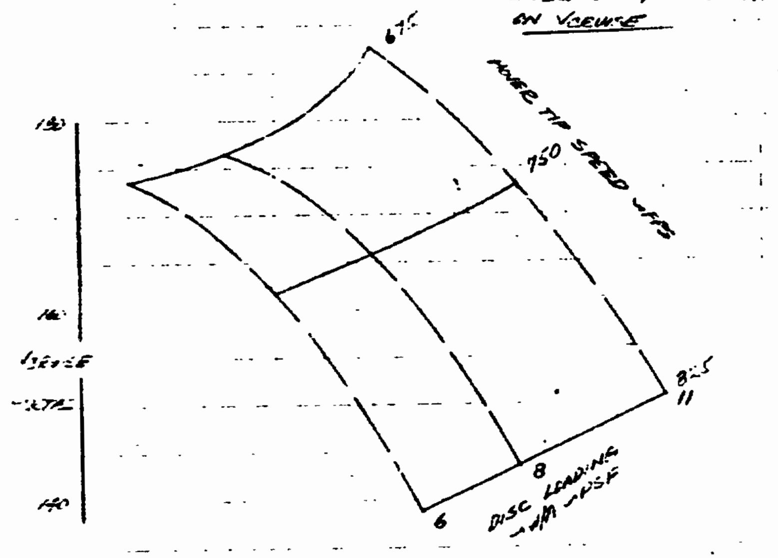
DISC LOADING (W/A) AND HOVER TIP SPEED (V_{TIP}) TRADES

σ/S = .09
3 ENGINES
V_C/V_{TH} = 1.0
NO OF PASS = 100
SEATS ACROSS = 7

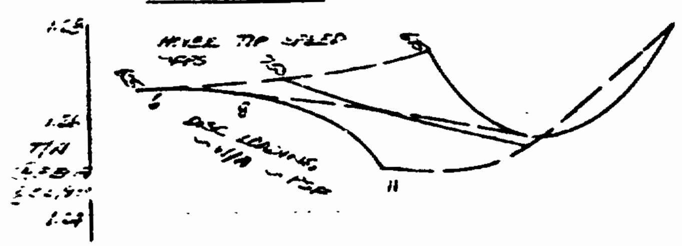
CRUISE ALTITUDE = 6500 FT.
CRUISE @ V_{MRP} OR
TORQUE LIMIT

TANDEM HELICOPTER

EFFECT OF W/A AND V_{TIP} ON V_{CRUISE}



EFFECT OF W/A AND V_{TIP} ON THRUST TO WEIGHT @ SL, 59°F, ALL ENGINES OPERATING



EFFECT OF W/A AND V_{TIP} ON SOLIDITY

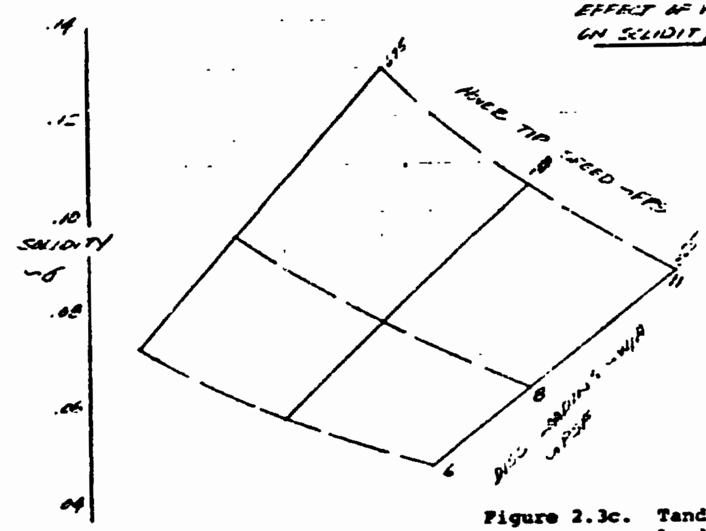


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Figure 2.3c. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 6,500 Feet.

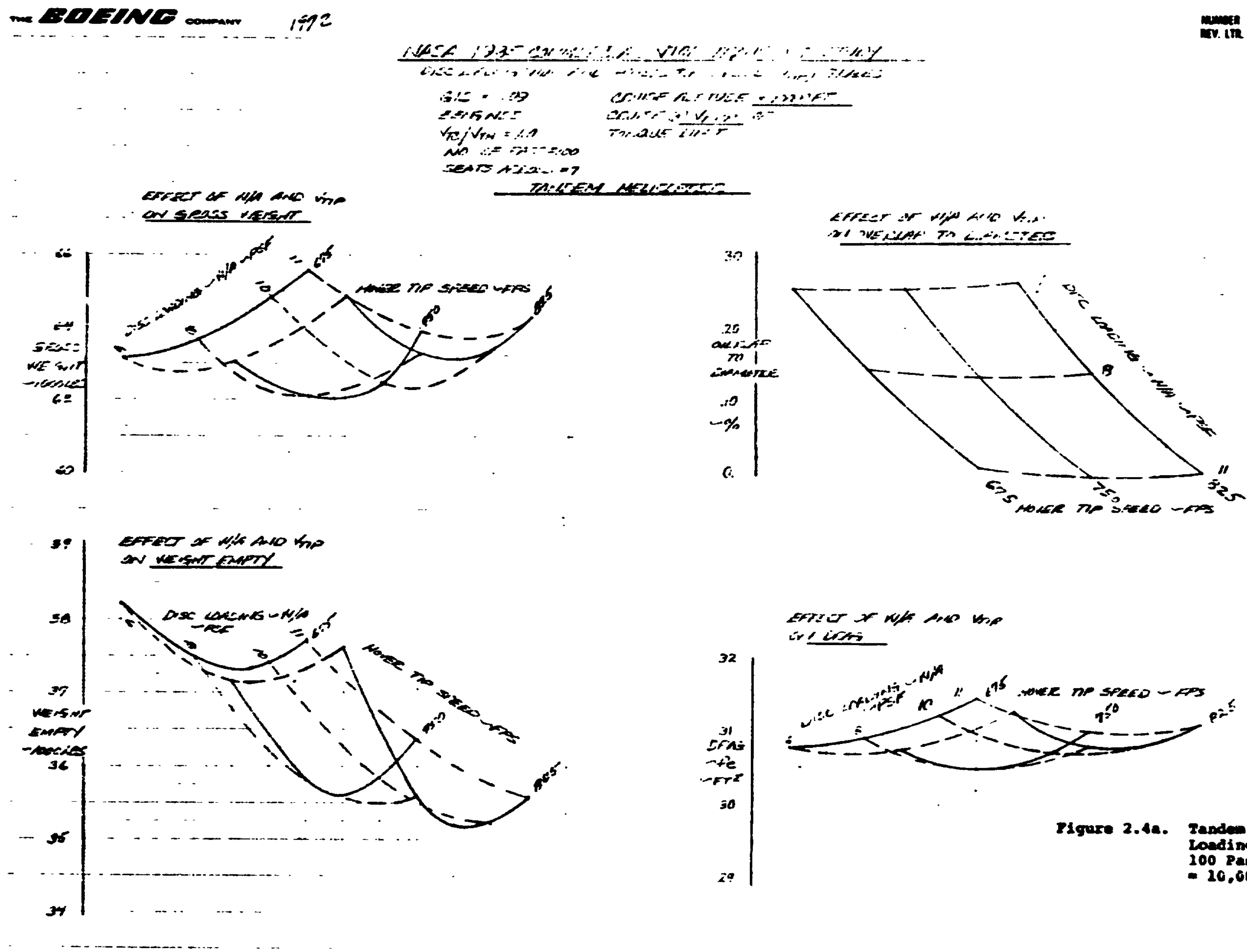

Figure 2.4a. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 10,000 Feet.

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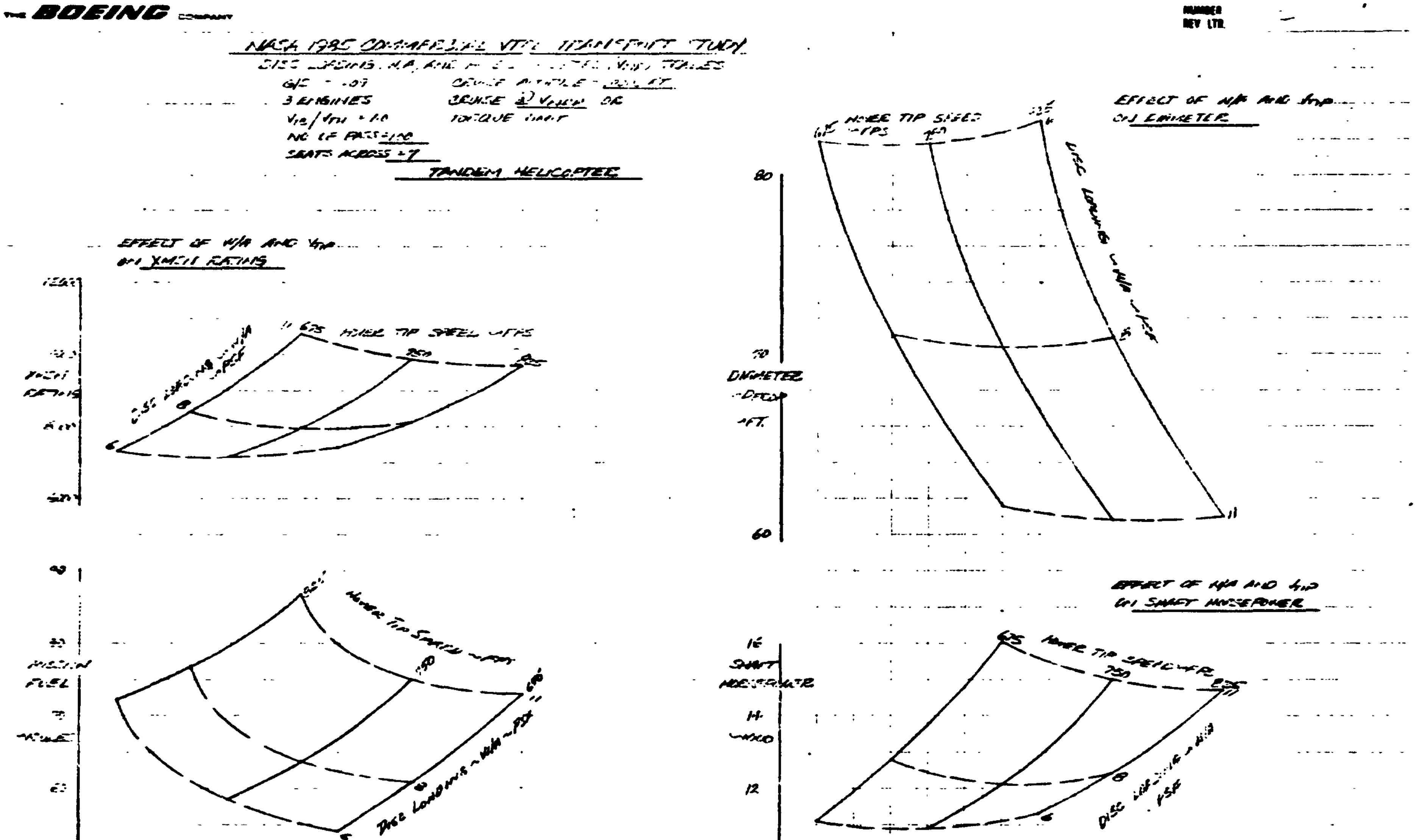

Figure 2.4b. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 10,000 Feet.

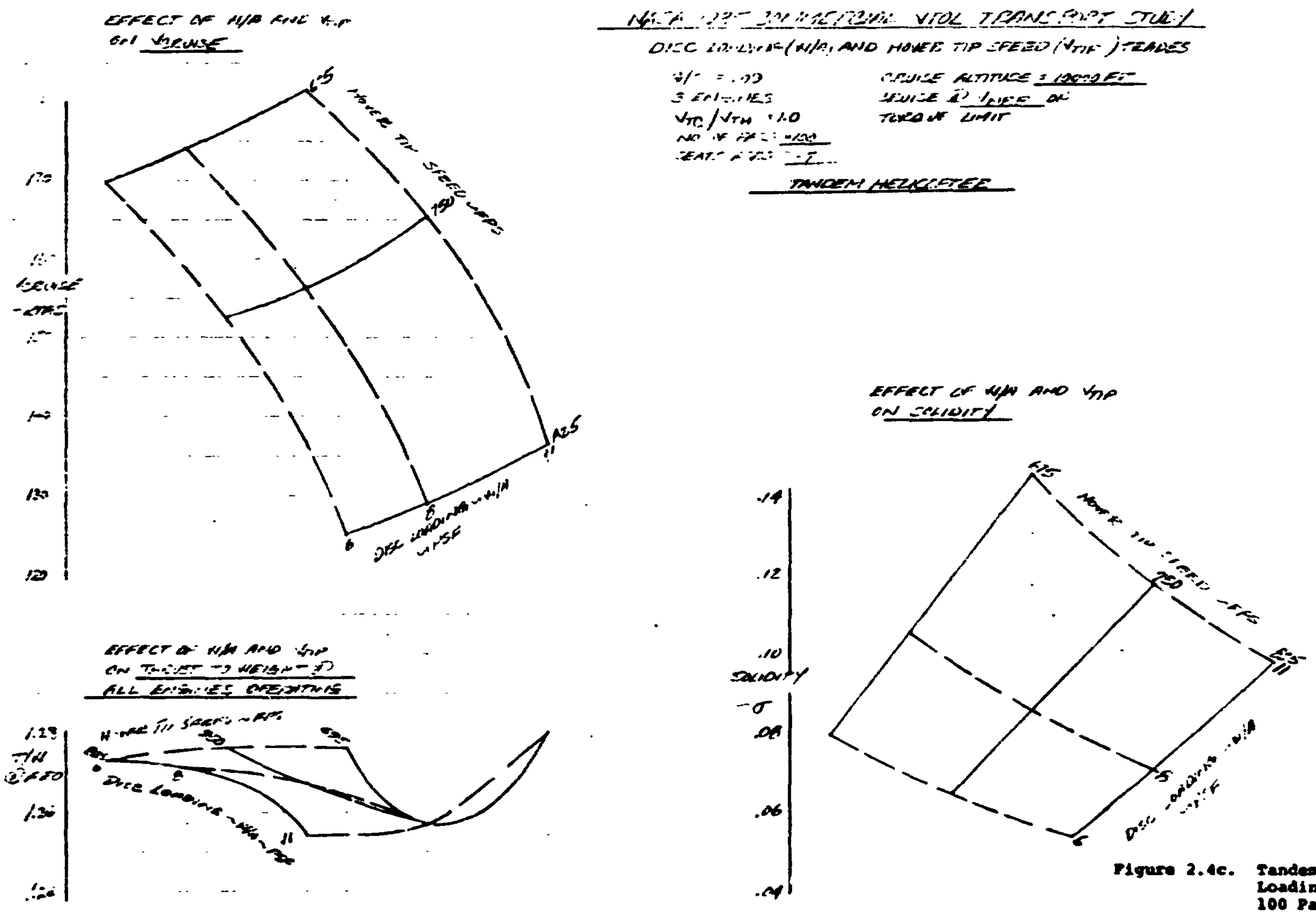

Figure 2.4c. Tandem Helicopter - Disc Loading and Tipspeed Trade, 100 Passengers. Altitude = 10,000 Feet.

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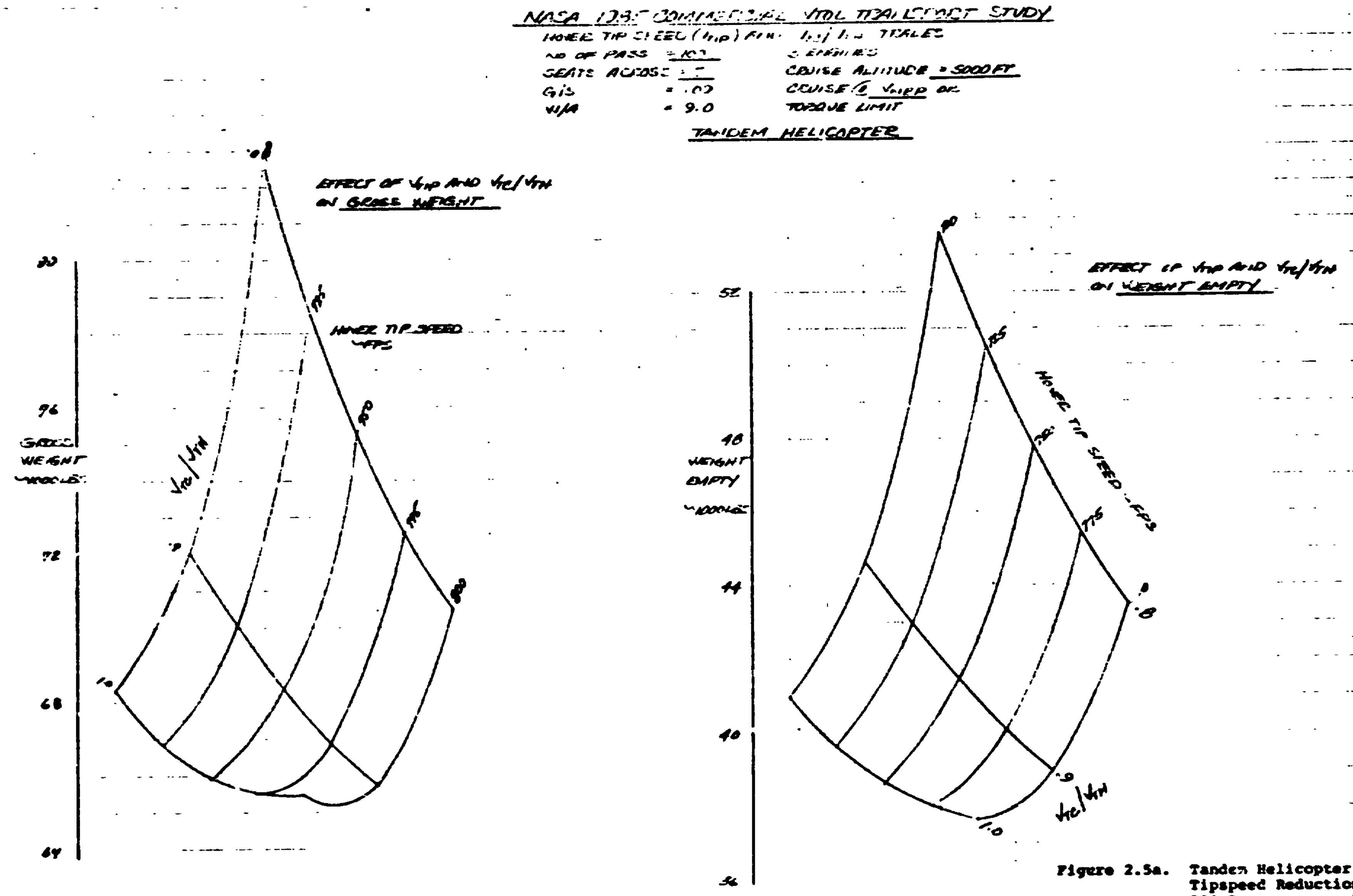


Figure 2.5a. Tandem Helicopter - Cruise Tipspeed Reduction Trade. 100 Passengers. Altitude = 5,000 Feet.

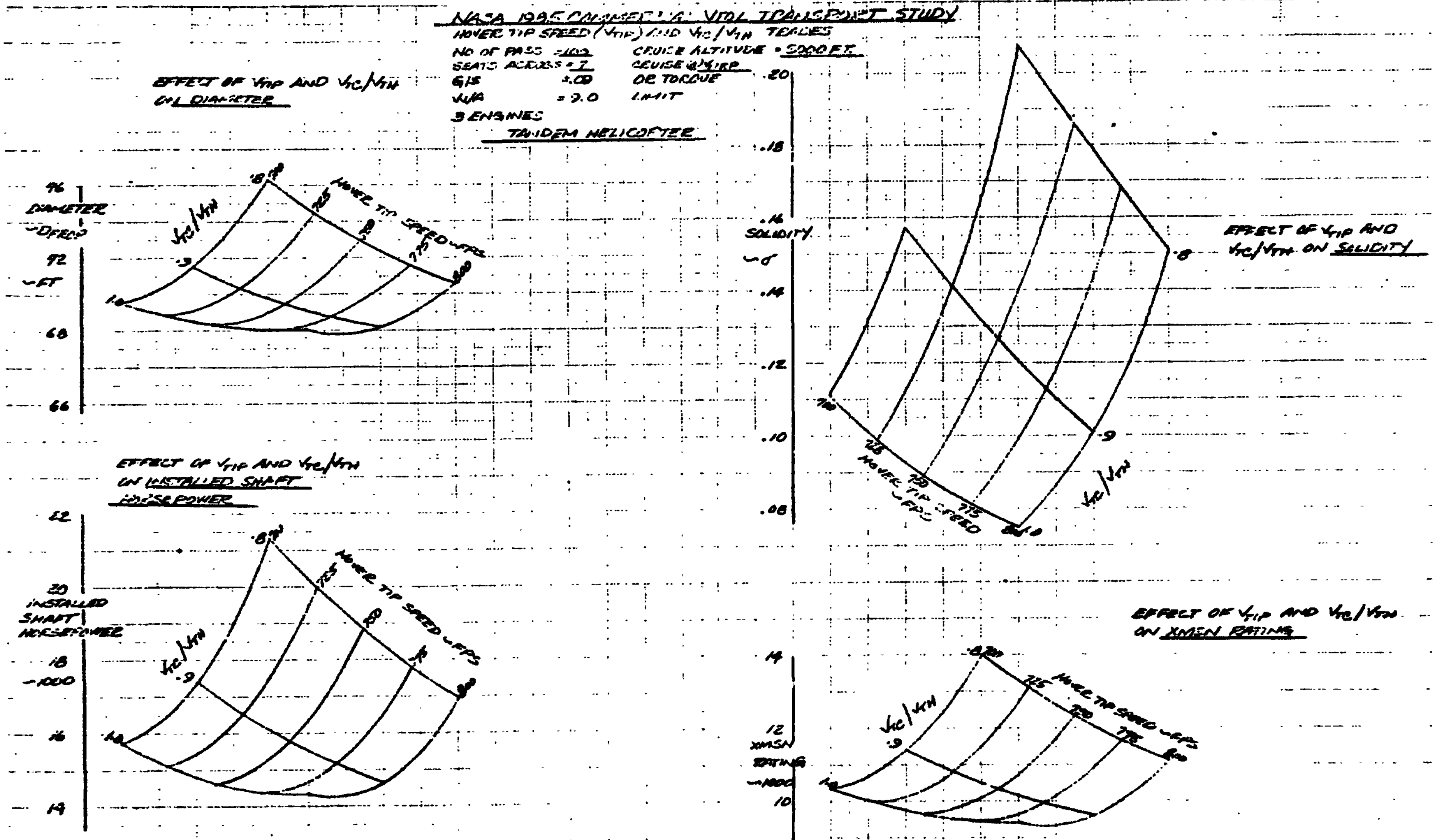


Figure 2.5b. Tandem Helicopter - Cruise Tipspeed Reduction Trade, 100 Passengers. Altitude = 5,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

HOVER TIP SPEED (V_{TIP}) AND V_{TC}/V_{TH} TRADES

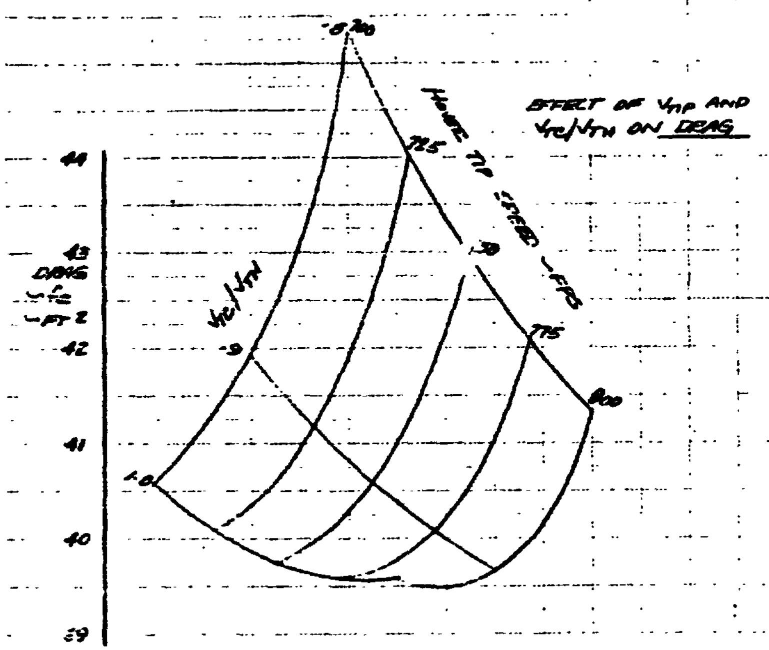
NO OF PASS 100 — 3 ENGINES

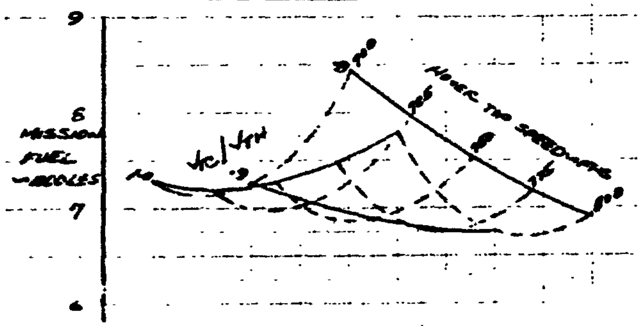
SEATS ACROSS 7 — CRUISE ALTITUDE 5000 FT

G/S = 0.9 — CRUISE @ V_{NRP} OR

W/A = 9.0 — TORQUE LIMIT.

TANDEM HELICOPTER





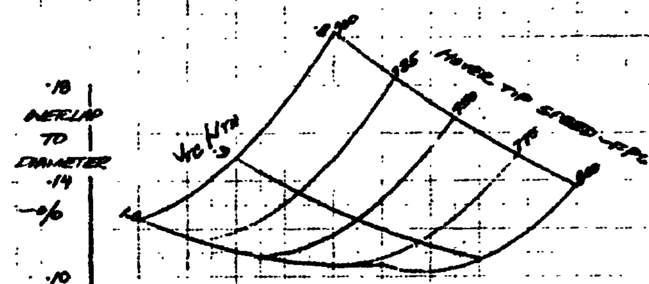


Figure 2.5c. Tandem Helicopter - Cruise Tipspeed Reduction Trade, 100 Passengers. Altitude = 5,000 Feet.

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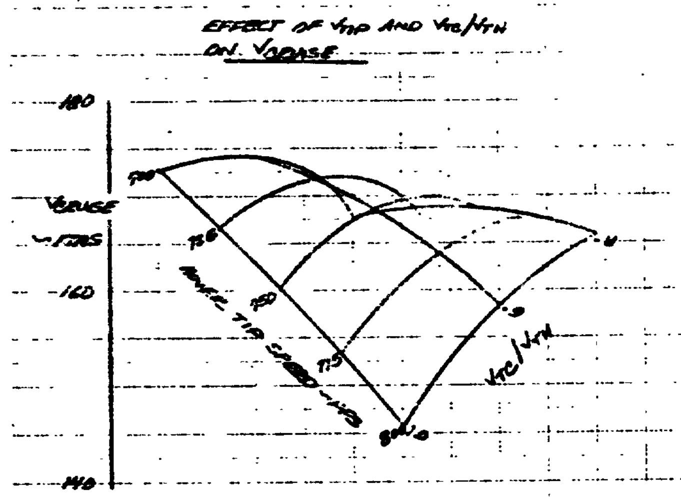
HOVER TIP SPEED (V_{TIP}) AND V_{TC}/V_{TH} TRADES

NO OF PASS = 100
SEATS ACROSS =
Q.E. = .09
W/A = 9.0

3 ENGINES
CRUISE ALTITUDE = 5000 FT
CRUISE @ V_{NEP} OR TORQUE LIMIT

TANDEM HELICOPTER



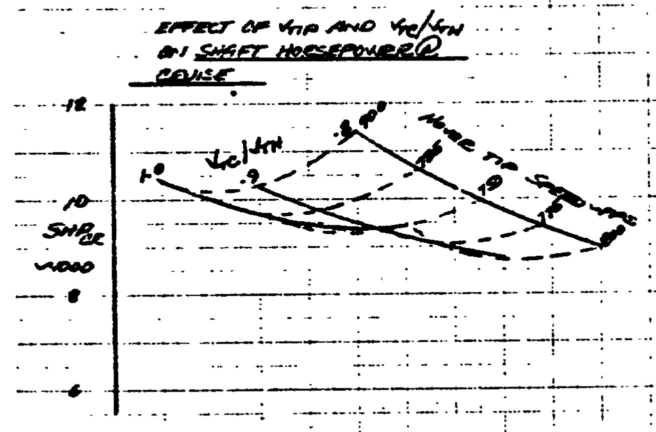


Figure 2.5d. Tandem Helicopter - Cruise Tipspeed Reduction Trade, 100 Passengers. Altitude = 5,000 Feet.

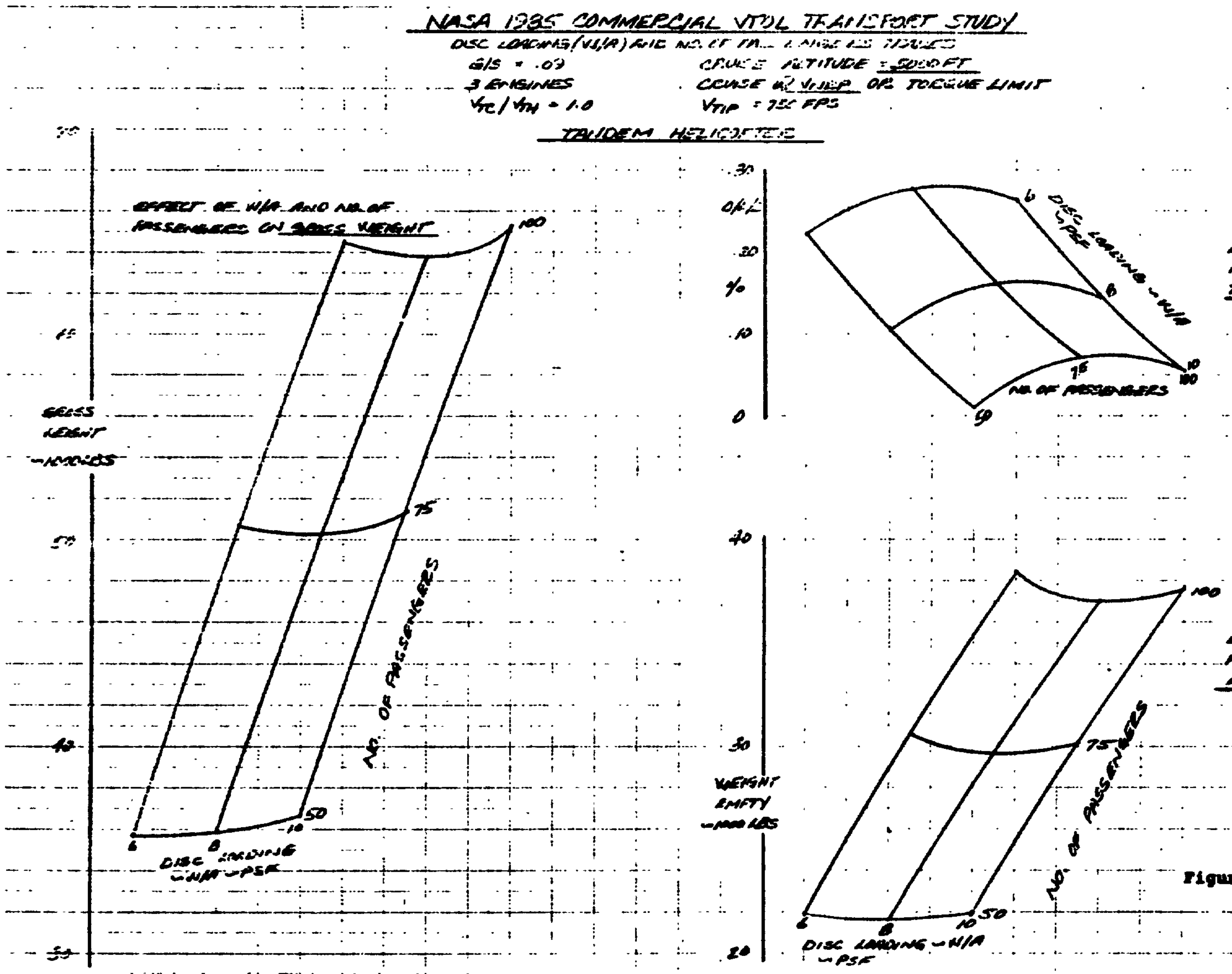


Figure 2.6a. Tandem Helicopter - Number of Passenger Trade. Tip-speed = 750 FPS. Altitude = 5,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND NO. OF PASSENGERS TRADES

G/S = .09
3 ENGINES
V_{TC}/V_{TH} = 1.0

CRUISE ALTITUDE = 5000 FT
CRUISE @ V_{MAX} OR TORQUE LIMIT
V_{TIP} = 750 FPS

TANDEM HELICOPTER

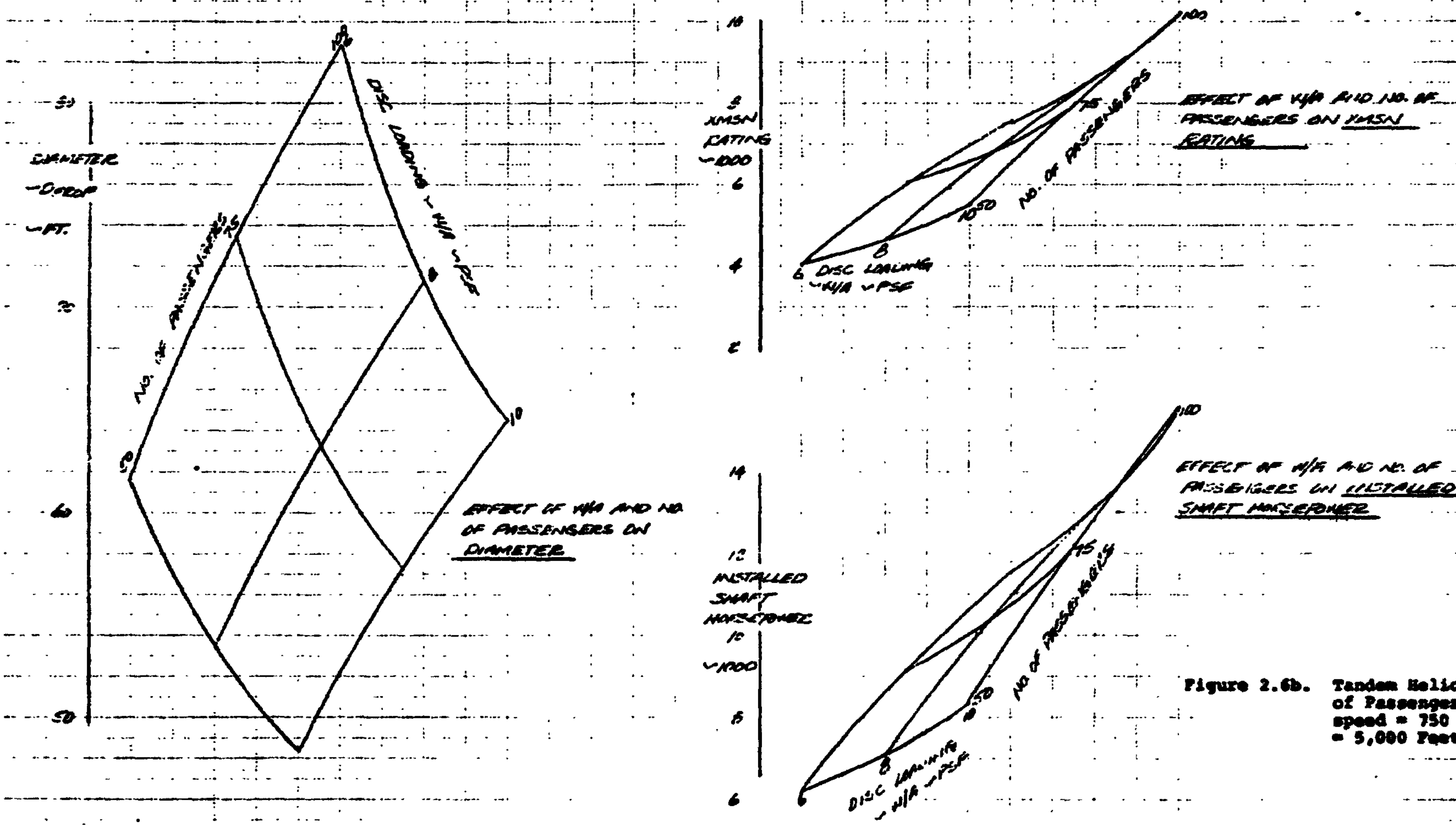


Figure 2.6b. Tandem Helicopter - Number of Passenger Trade. Tip-speed = 750 FPS. Altitude = 5,000 Feet.

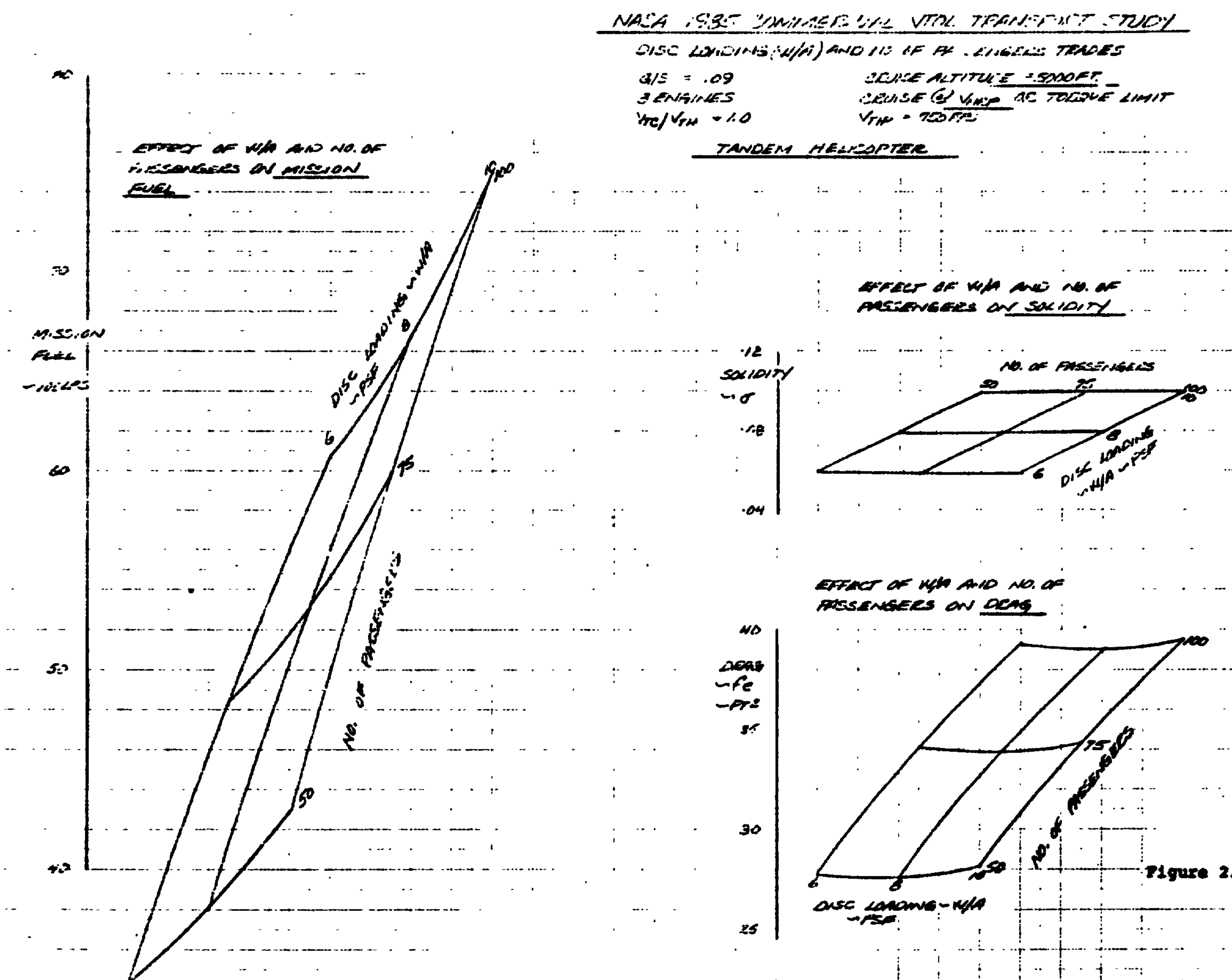


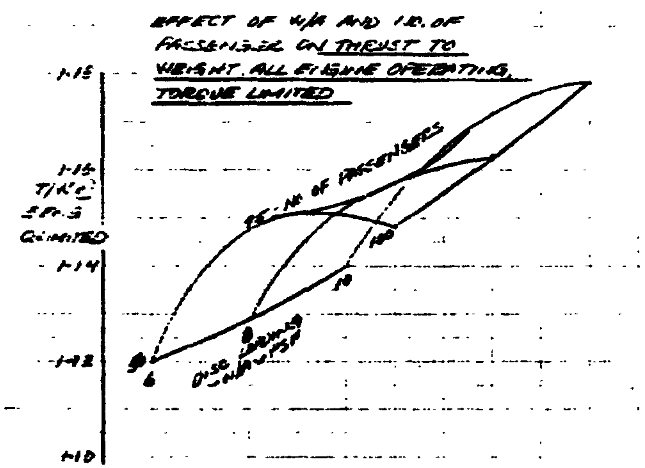
Figure 2.6c. Tandem Helicopter - Number of Passenger Trade. Tip-speed = 750 FPS. Altitude = 5,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND NO. OF PASSENGERS TRADES

G/S = .07	CRUISE ALTITUDE = 5000 FT.
3 ENGINES	CRUISE @ V_{NRP} OR TORQUE LIMIT
V_{TC}/V_{TH} = 1.0	V_{TIP} = 750 FPS

TANDEM HELICOPTER



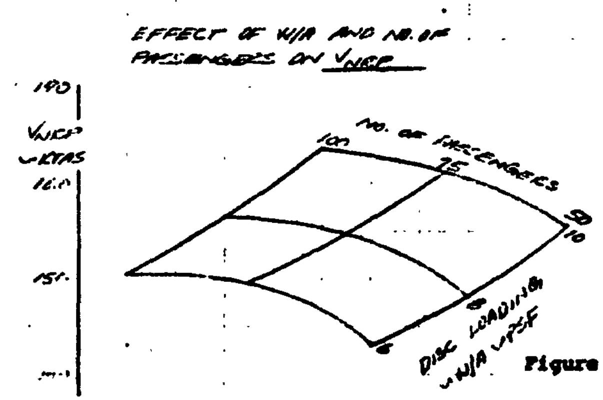


Figure 2.6d. Tandem Helicopter - Number of Passenger Trade. Tip-speed = 750 FPS. Altitude = 5,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND NO. OF PASSENGERS

W/S = .09 — CRUISE = 5000 FT

V_{TIP} = 750 FPS — CRUISE @ V_{NRC}

V_{TIP}/V_{TIH} = 1.0 — REVISED WEIGHTS

3 ENGINES

TANDEM HELICOPTER

EFFECT OF W/A AND NO. OF PASSENGER ON TOTAL FUEL

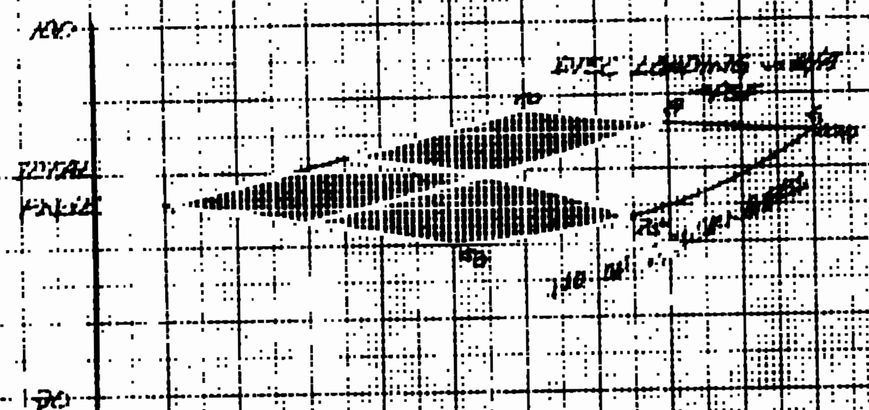


Figure 2.6a. Tandem Helicopter — Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 2,000 Feet.

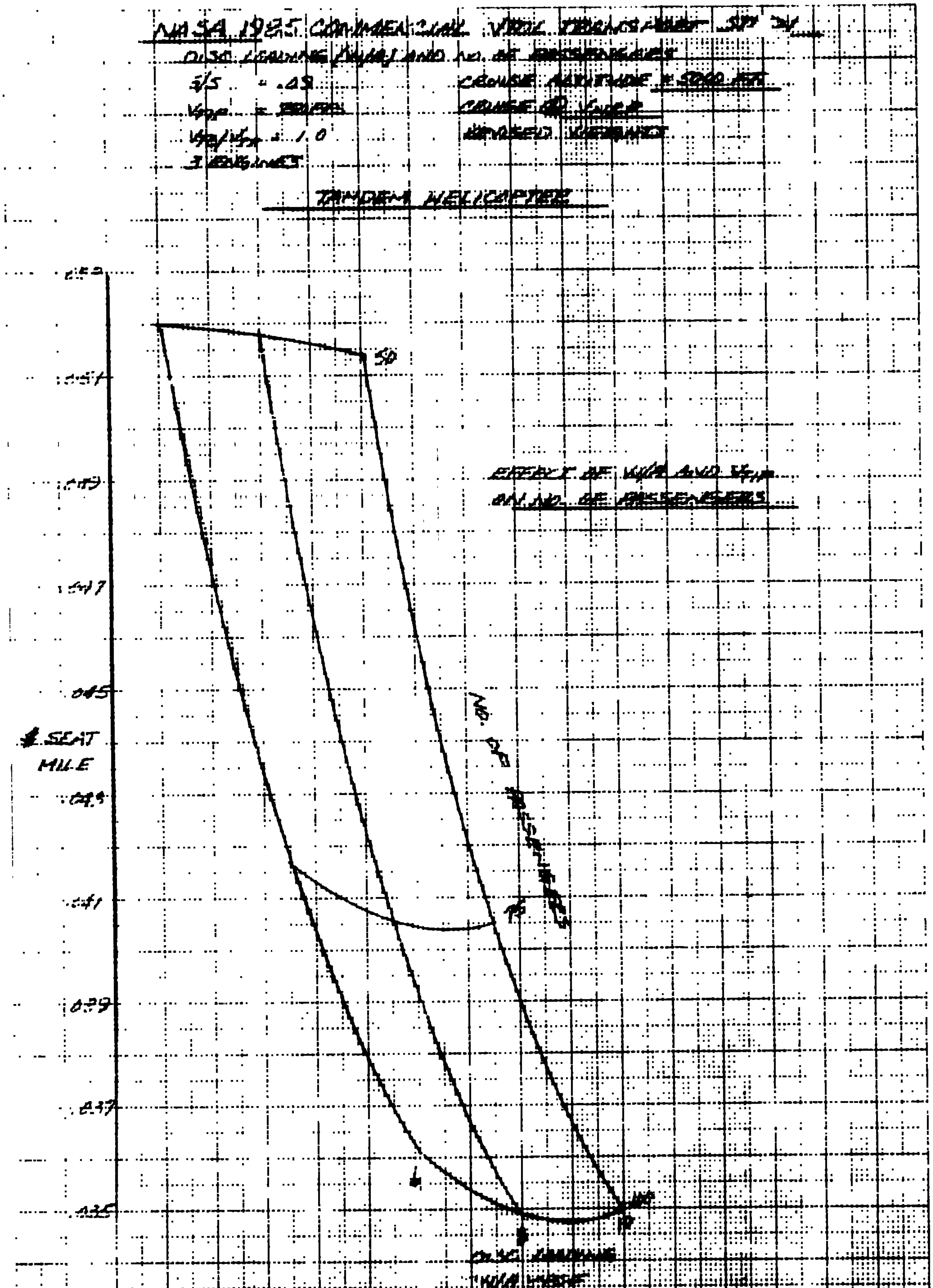
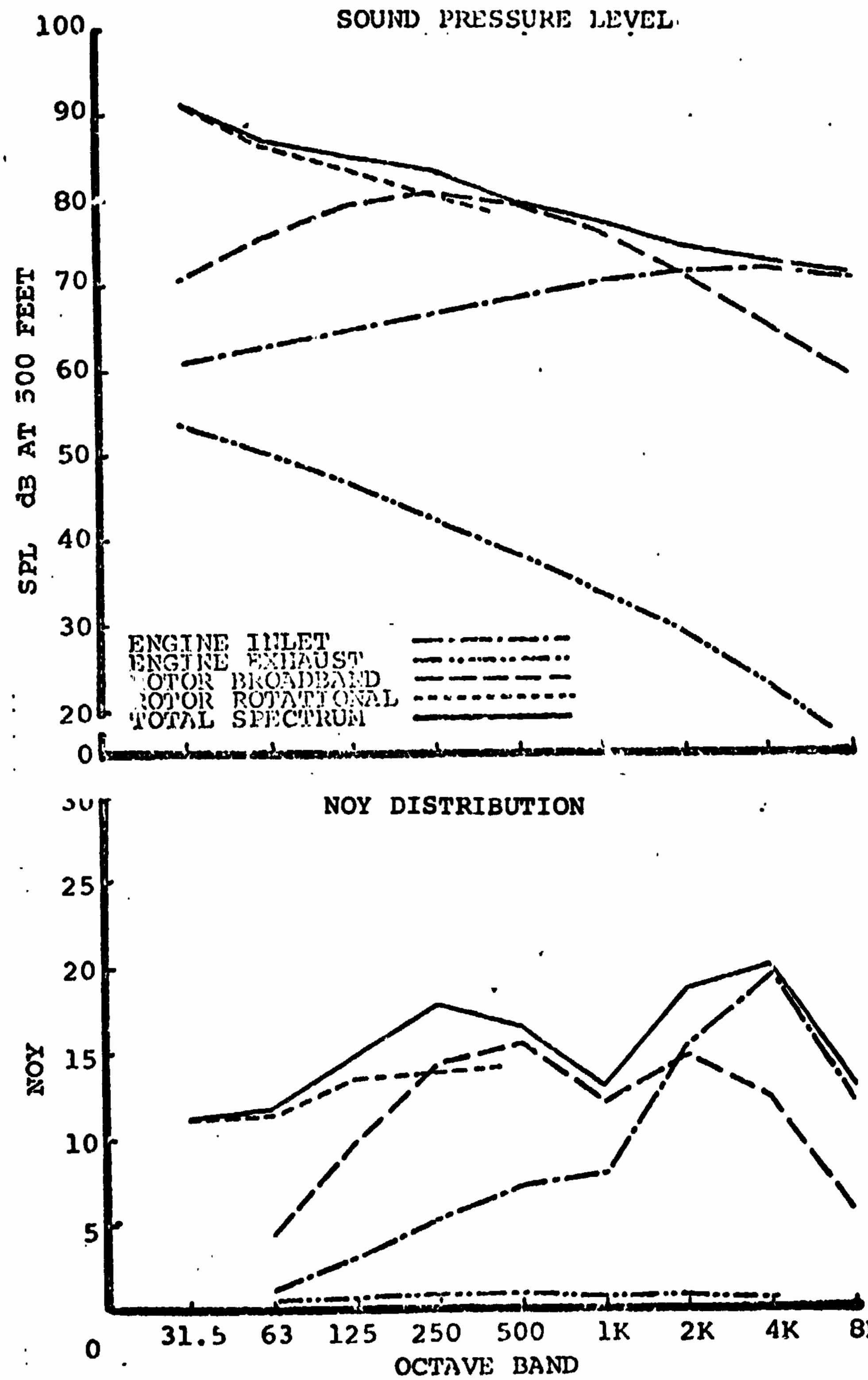
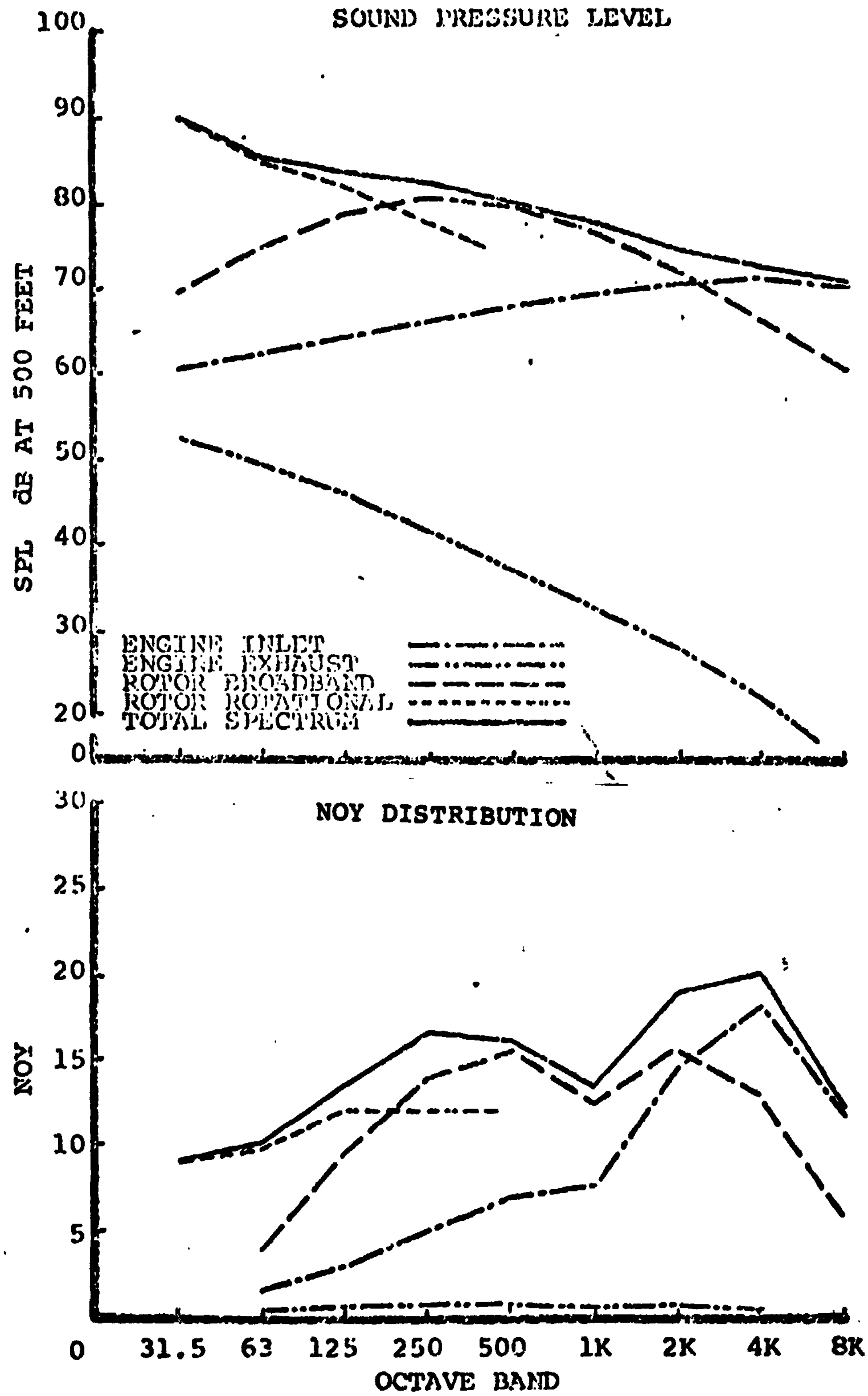


Figure 2.6f. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet.



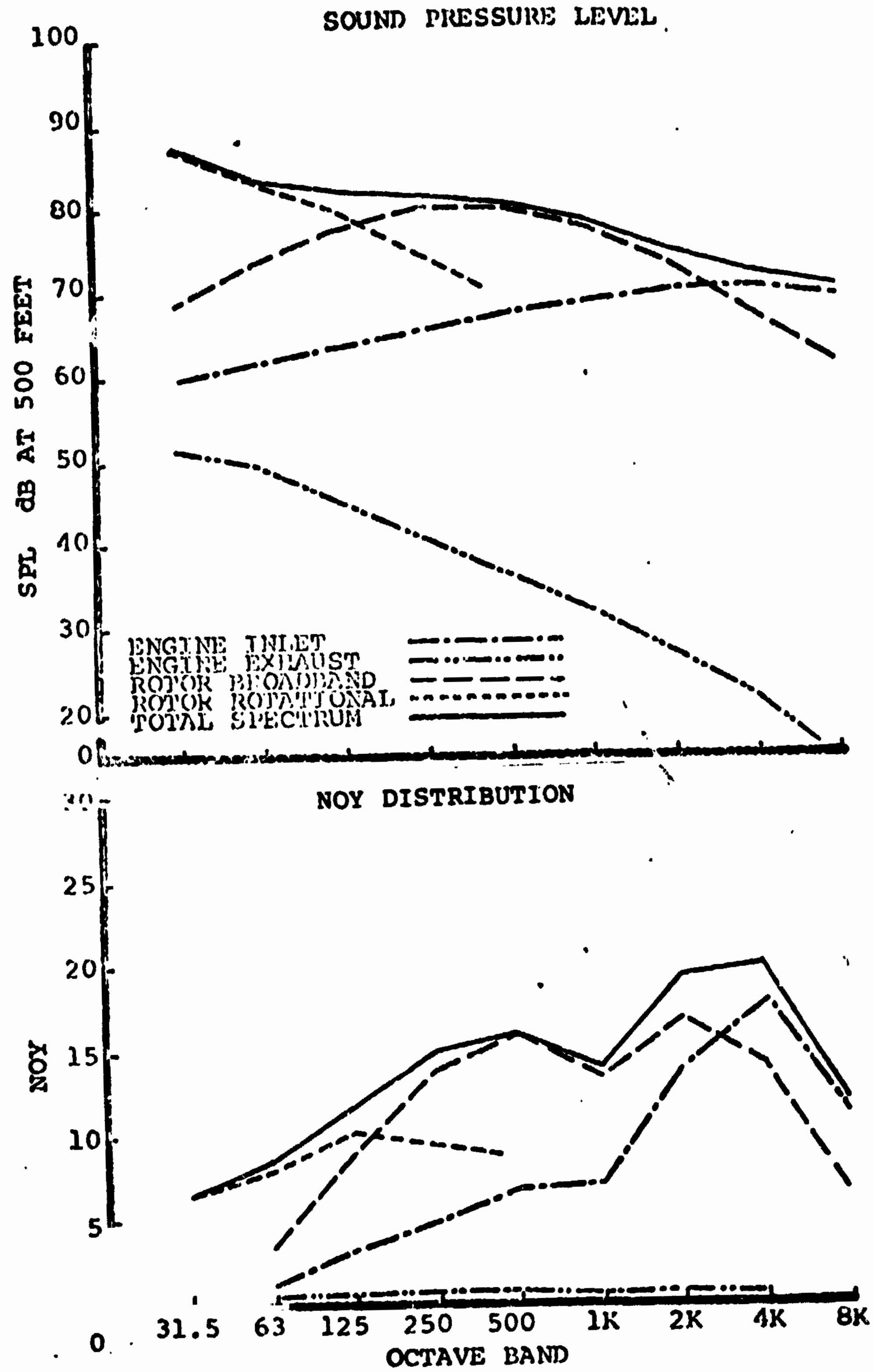
HELICOPTER, CASE 1, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A = 10 - PNdB 97.9

Figure 2.6g. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet.



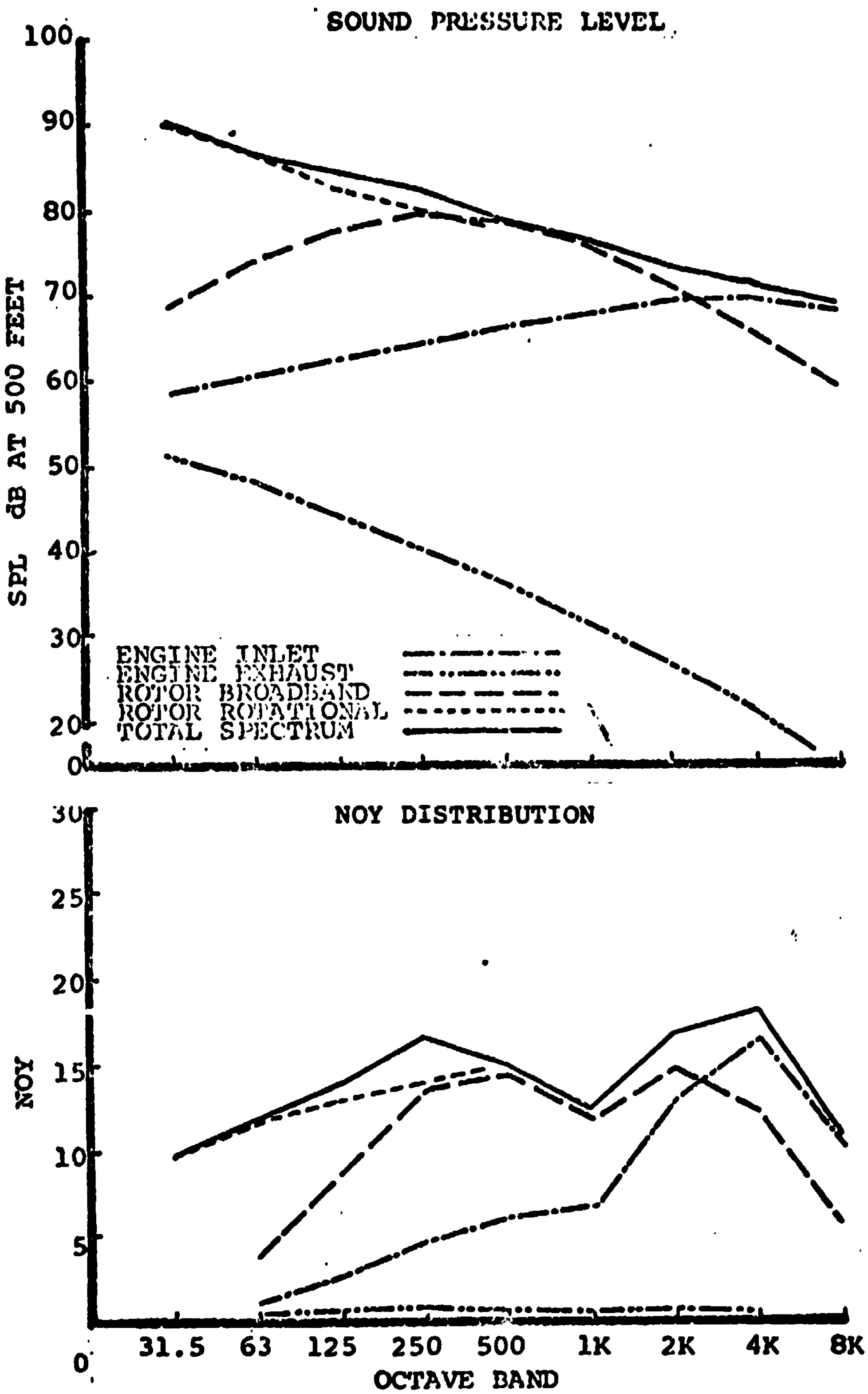
HELICOPTER, CASE 2, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A = 8, PNdB = 97.4

Figure 2.6h. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet.



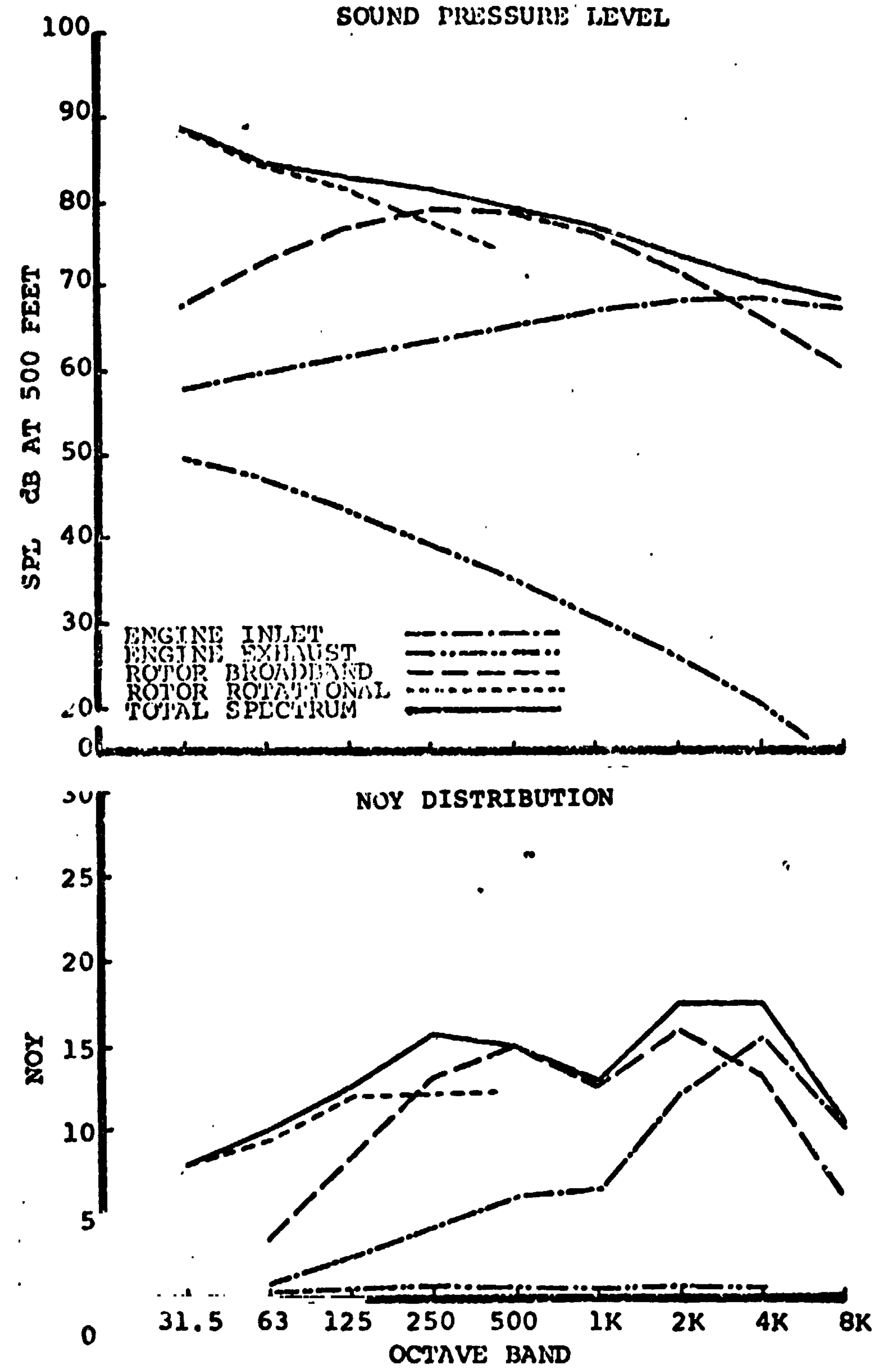
HELICOPTER, CASE 3, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A =6, PNdB = 96.9

Figure 2.6i. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet.



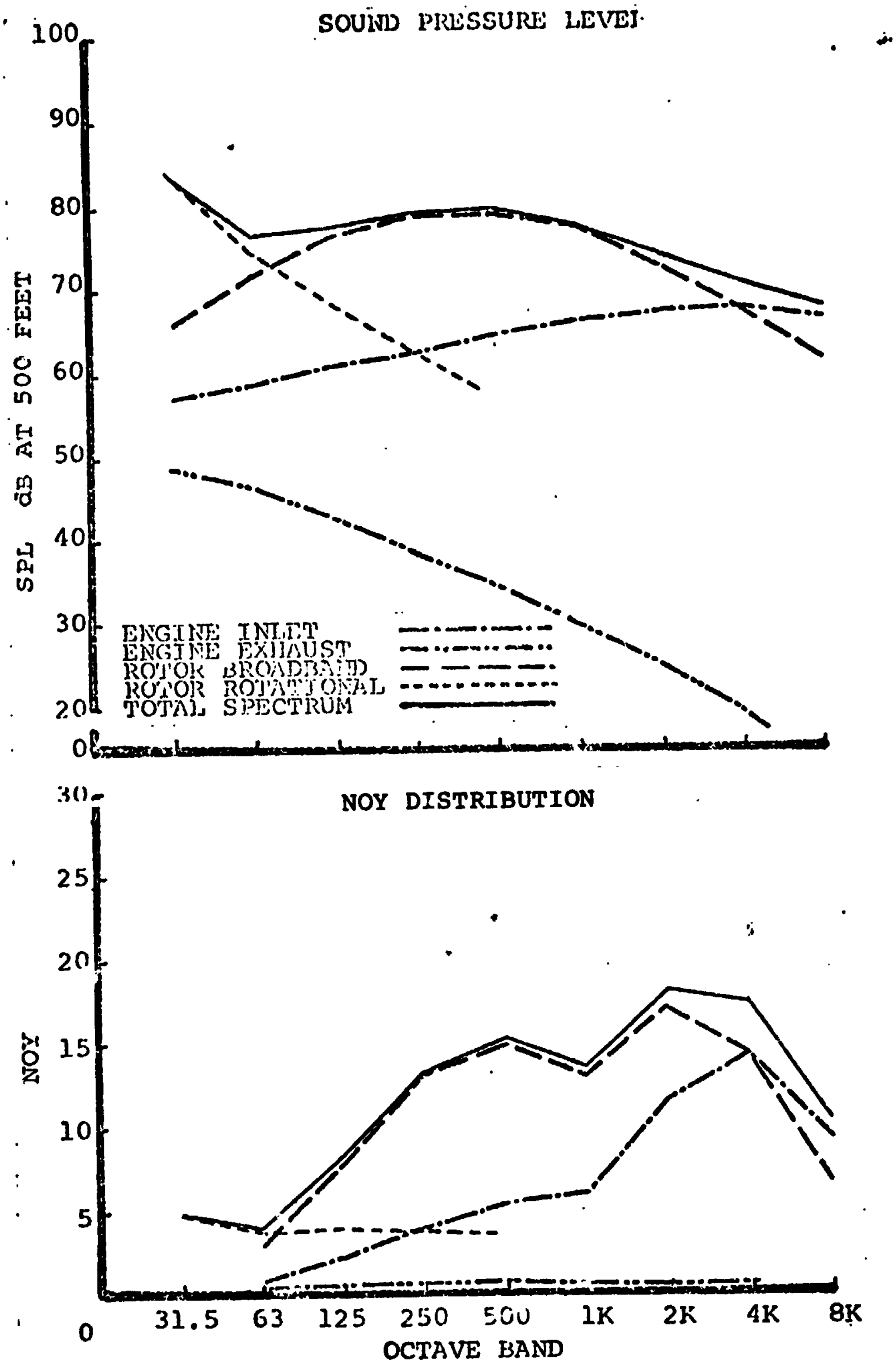
HELICOPTER, CASE 4, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 75 PASSENGERS, VT = 750, W/A = 10, PNdB = 96.7

Figure 2.6j. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet.



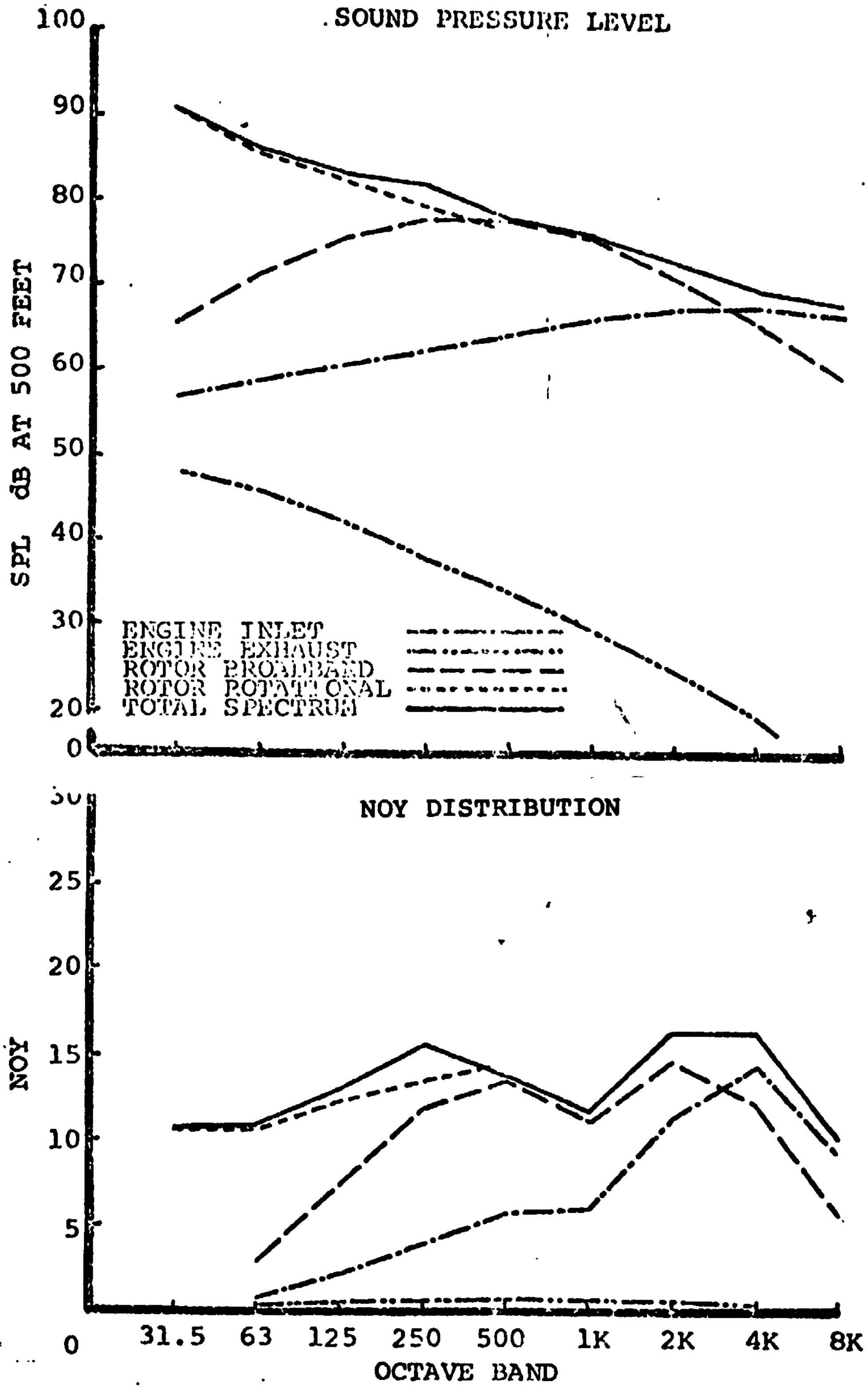
HELICOPTER, CASE 5, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 75 PASSENGERS, VT = 750, W/A = 8, PNdB = 96

Figure 2.6k. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Ft.



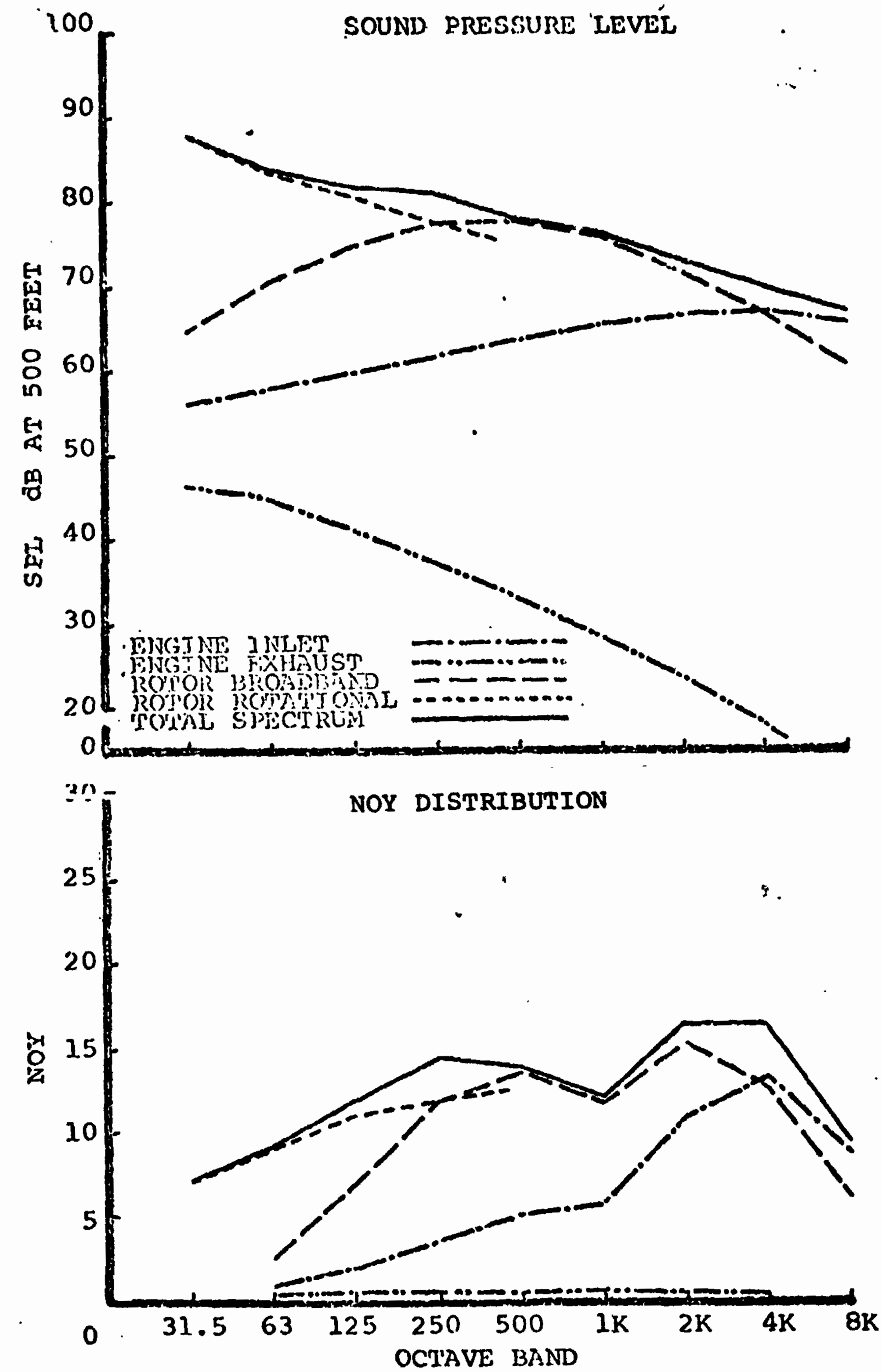
HELICOPTER, CASE 6, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 75 PASSENGERS, VT = 750, W/A = 6, PNdB = 94.7

Figure 2.61. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet



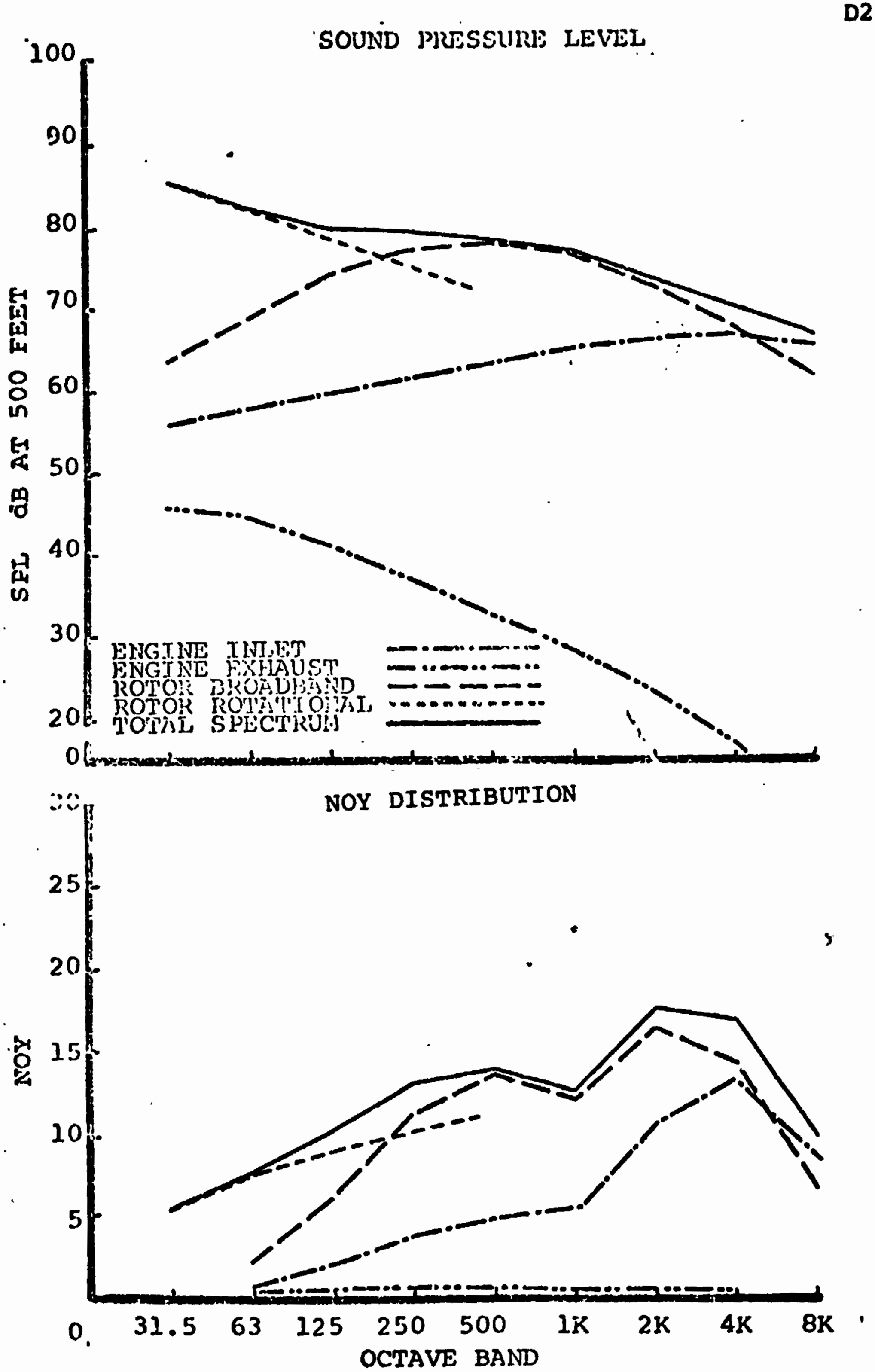
HELICOPTER, CASE 7, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 50 PASSENGERS, VT = 750, W/A = 10, PNdB = 95.7

Figure 2.6m. Tandem Helicopter - Number of Passenger Trade. Tipspeed - 750 FPS. Altitude = 5,000 Feet.



HELICOPTER, CASE 8, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 50 PASSENGERS, VT = 750, W/A = 8, PNdB = 94.9

Figure 2.6n. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. ALTITUDE = 5,000 Ft.



HELICOPTER, CASE 9, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 50 PASSENGERS, VT = 750, W/A = 6, PNdB = 94.8

Figure 2.6o. Tandem Helicopter - Number of Passenger Trade. Tipspeed = 750 FPS. Altitude = 5,000 Feet.

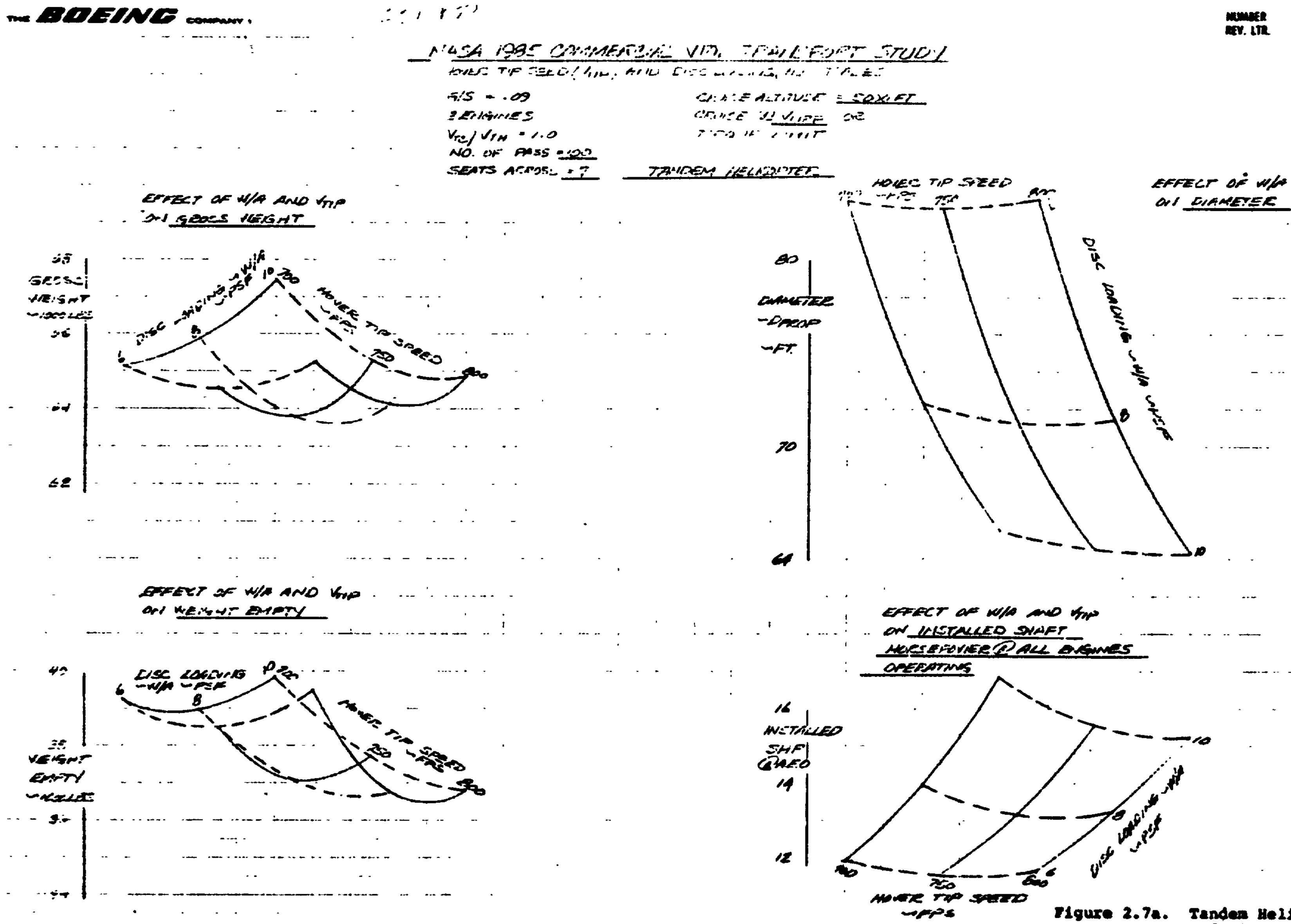


Figure 2.7a. Tandem Helicopter - Tipspeed and Disc Loading Trade, 100 Passengers. Altitude = 5,000 Feet.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

HOVER TIP SPEED (V_{TIP}) AND DISC LOADING

B/S = .99
3 ENGINES
V_{TO}/V_{TH} = 1.0
NO. OF PASS = 100
SEATS ACROSS = 7

CRUISE ALTITUDE = 5000 FT
CRUISE @ V_{MCP} OR
TORQUE LIMIT

TANDEM HELICOPTER

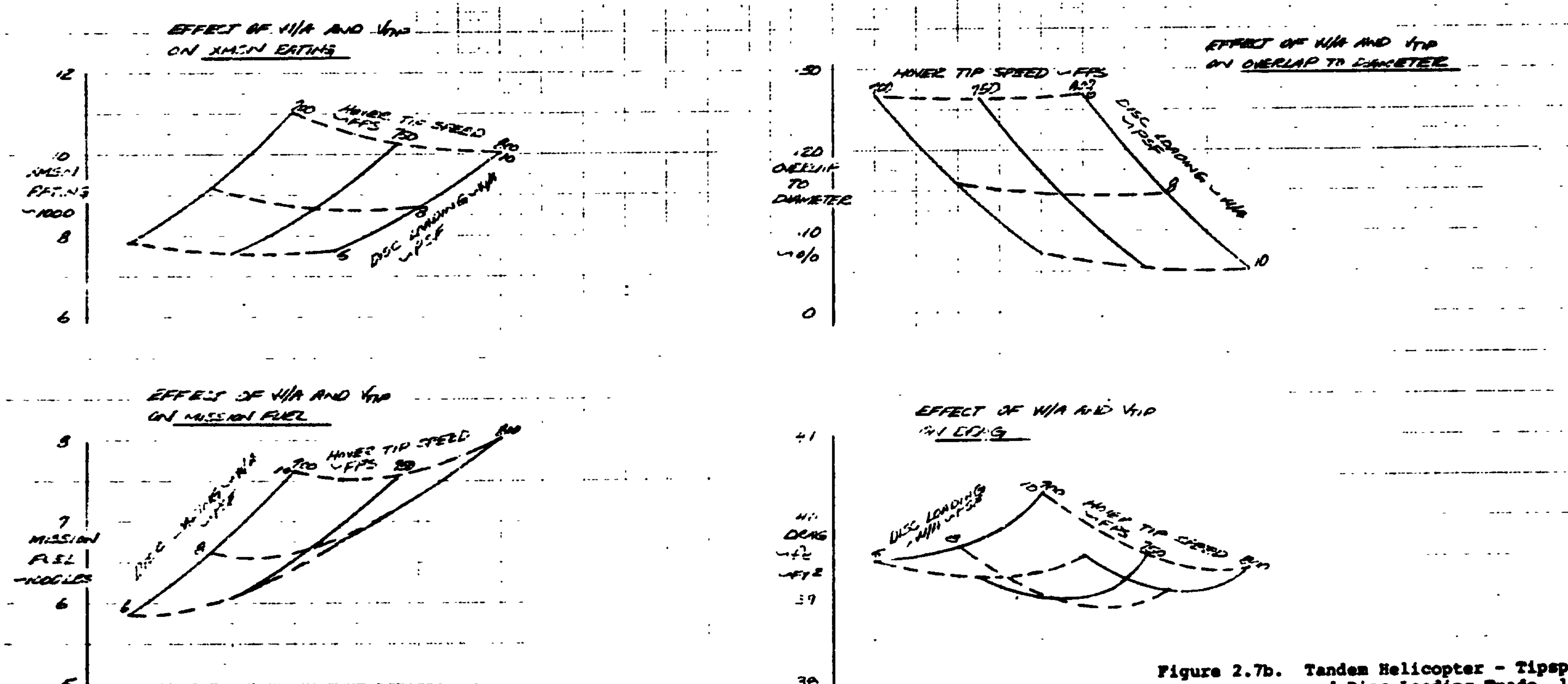

Figure 2.7b. Tandem Helicopter - Tipspeed and Disc Loading Trade. 100 Passengers. Altitude = 5,000 Feet.

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REV LTR.

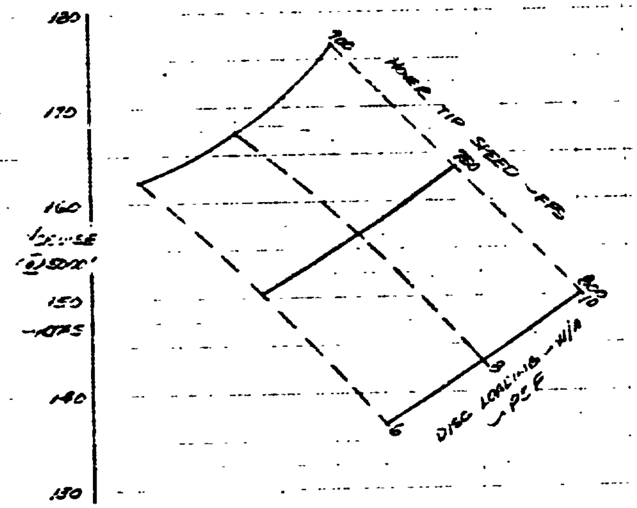
NASA OBE COMMERCIAL VTOL TRANSPORT STUDY
HOVER TIP SPEED (V_{TIP}) AND DISC LOADING (W/A) TRADES

$\sigma/\sigma = .07$
3 ENGINES
$V_{TIP}/V_{TIP} = 1.0$
NO OF PASS = 100
SEATS ACROSS = 7

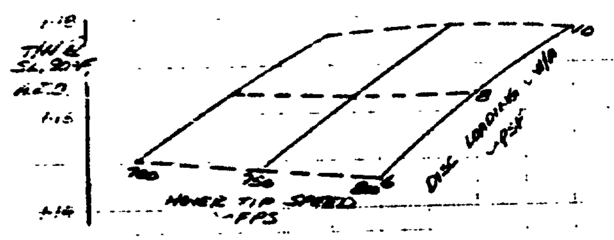
CRUISE ALTITUDE = 5000 FT
CRUISE @ V_{MRP} OR TORQUE LIMIT

TANDEM HELICOPTER

EFFECT OF W/A AND V_{TIP} ON V_{CRUISE} @ 5000 FT.



EFFECT OF W/A AND V_{TIP} ON THRUST TO WEIGHT @ SL 90°F, ALL ENGINES OPERATING



EFFECT OF W/A AND V_{TIP} ON SOLIDITY

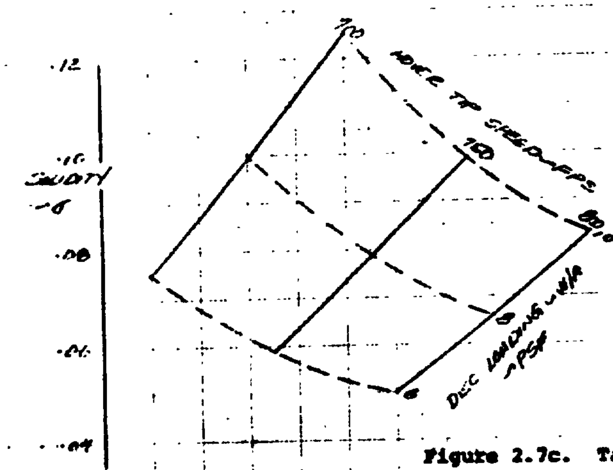


Figure 2.7c. Tandem Helicopter - Tipspeed and Disc Loading Trade. 100 Passengers. Altitude = 5,000 Feet.

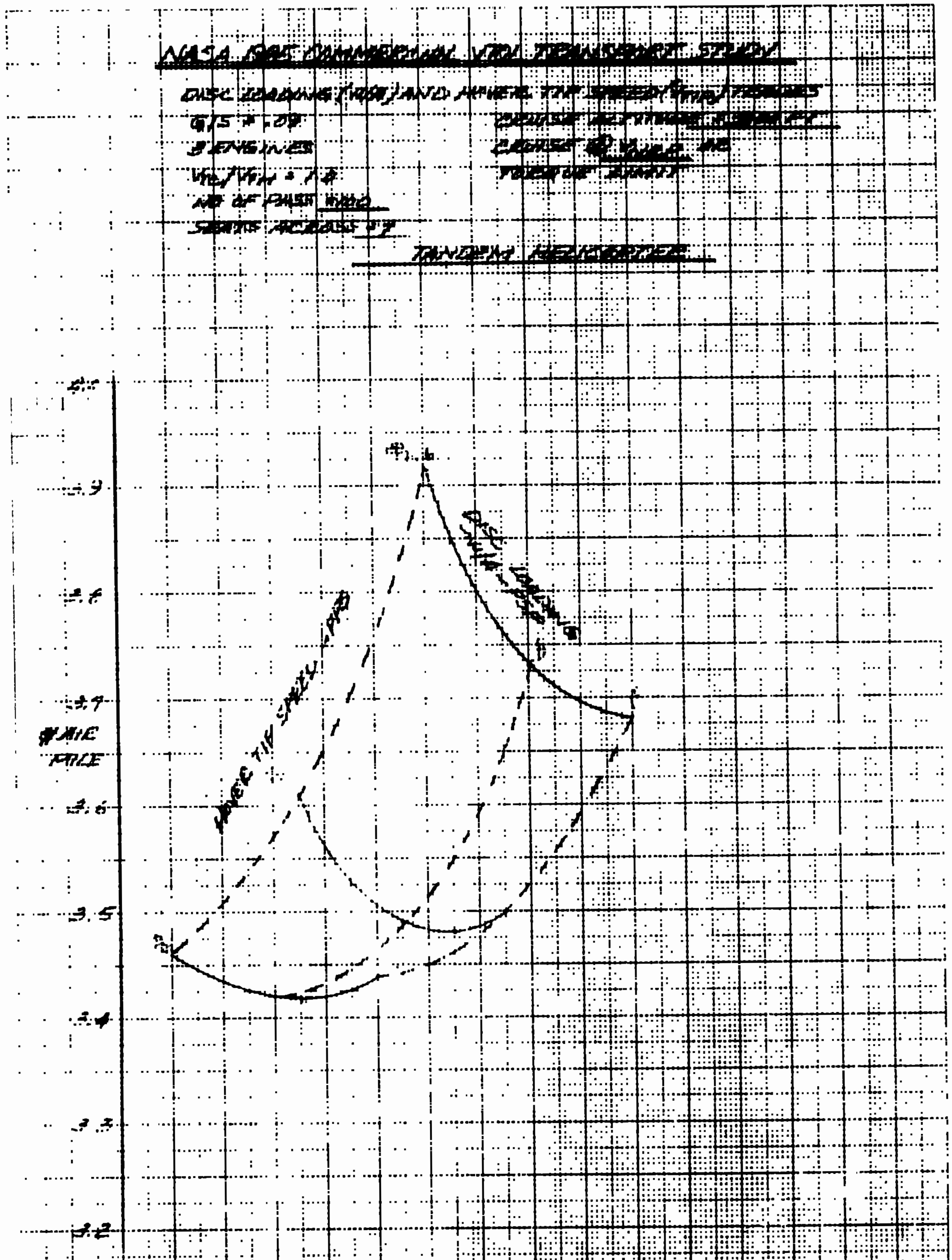
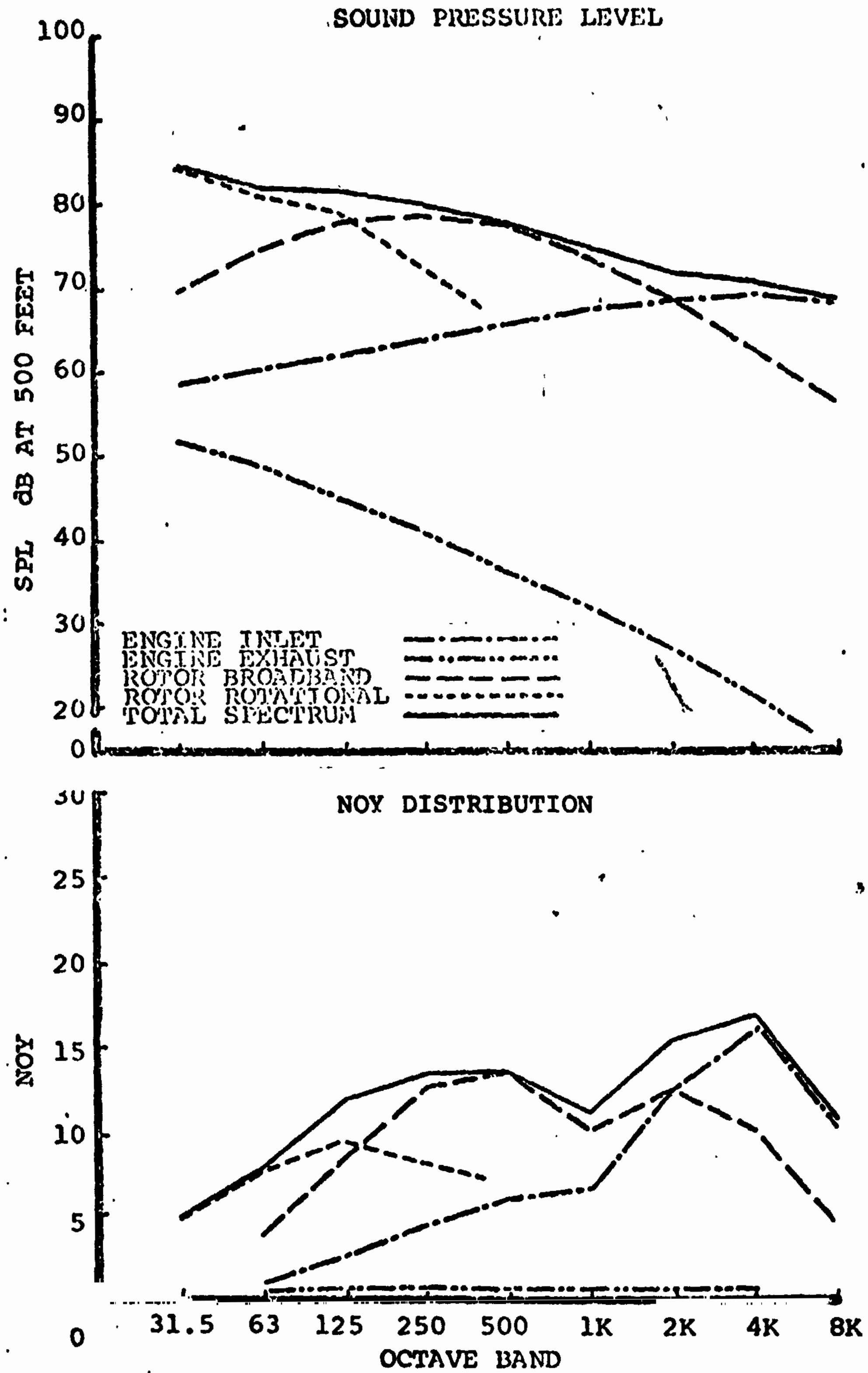
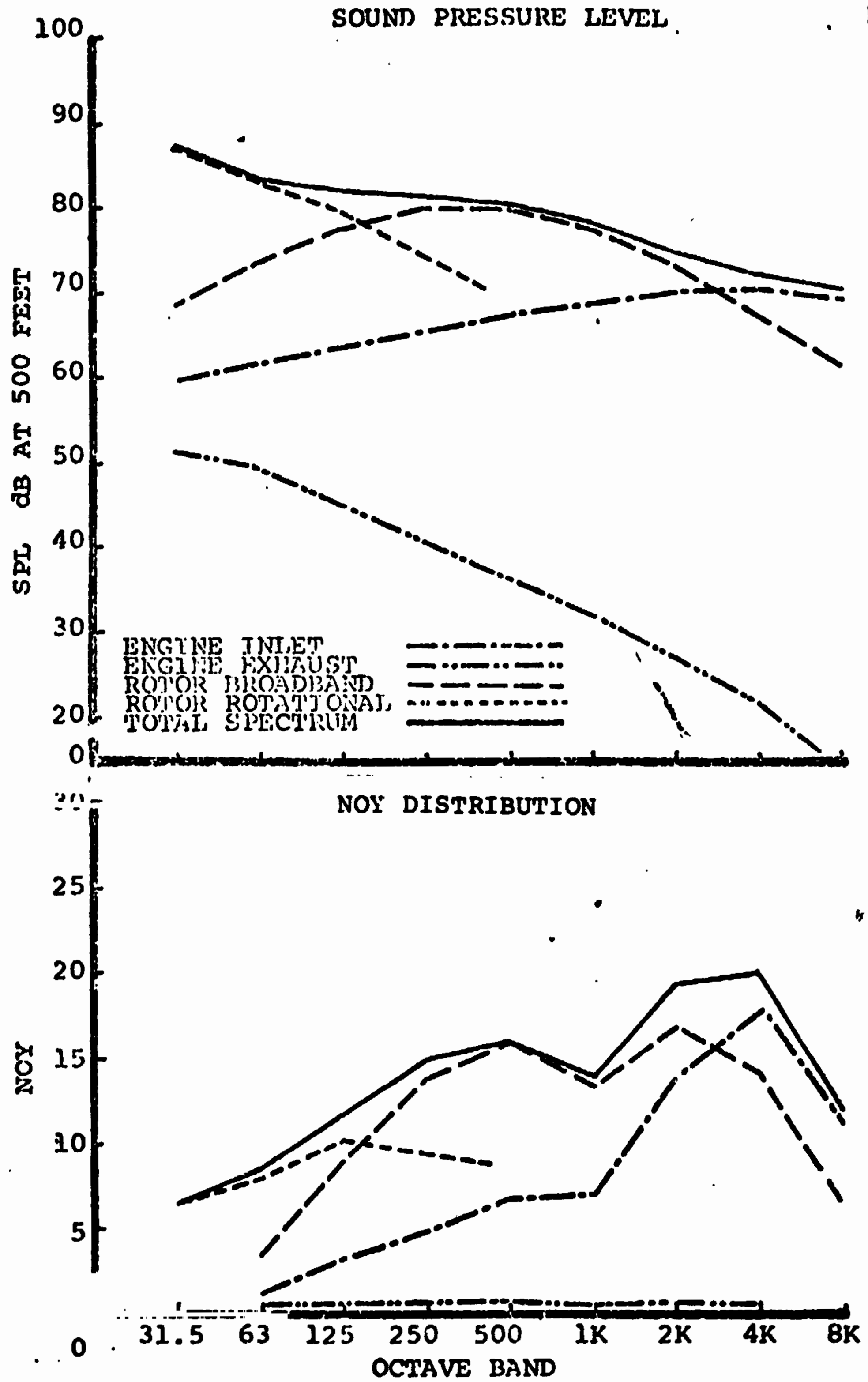


Figure 2.78. Tandem Helicopter - Tipspeed and Disc Loading Trade, 100 Passengers. Altitude = [illegible] Feet.



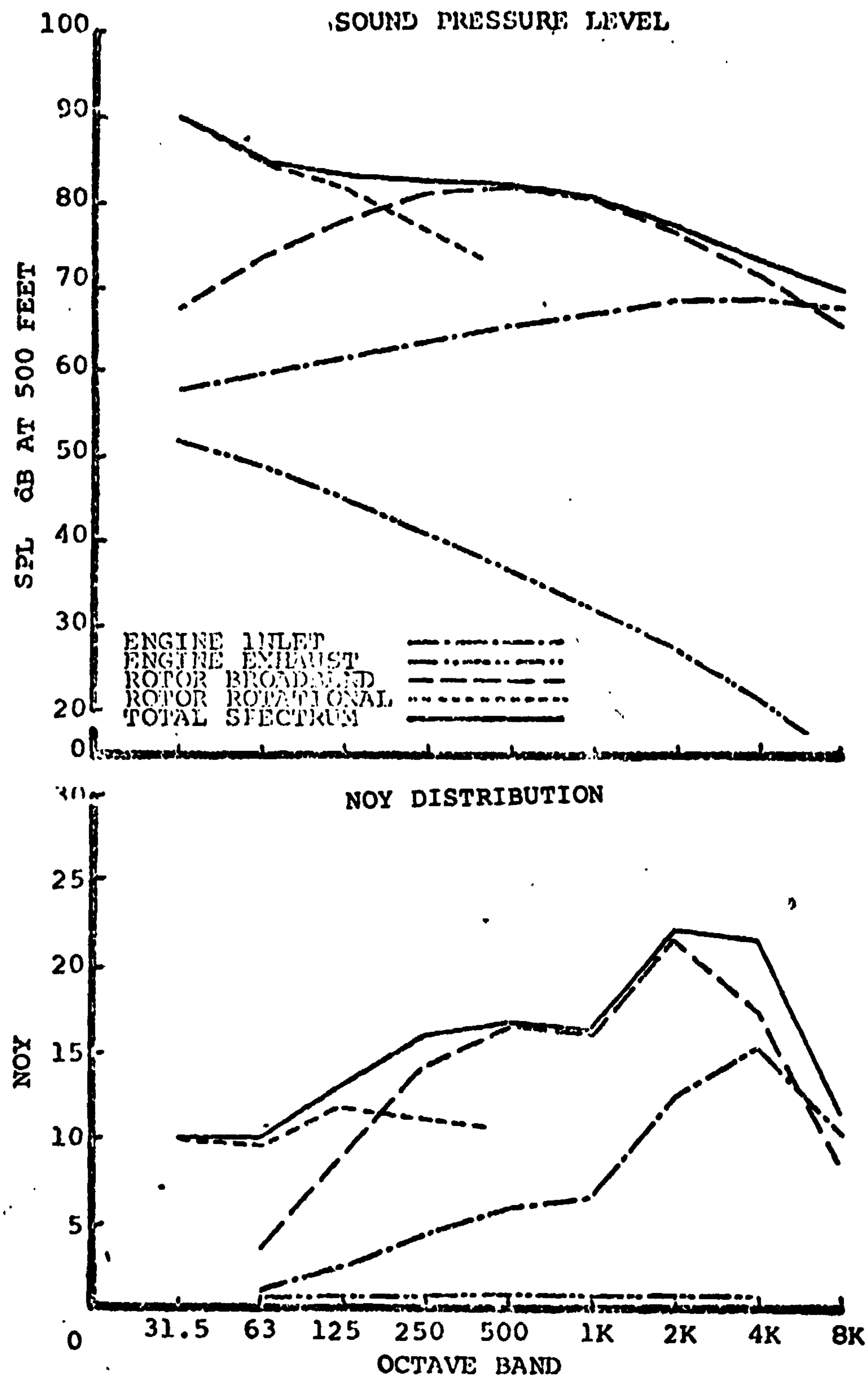
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 700, W/A = 6, PNdB = 94.5

Figure 2.7e. Tandem Helicopter - Tipspeed and Disc Loading Trade, 100 Passengers. Altitude = 5,000 Ft.



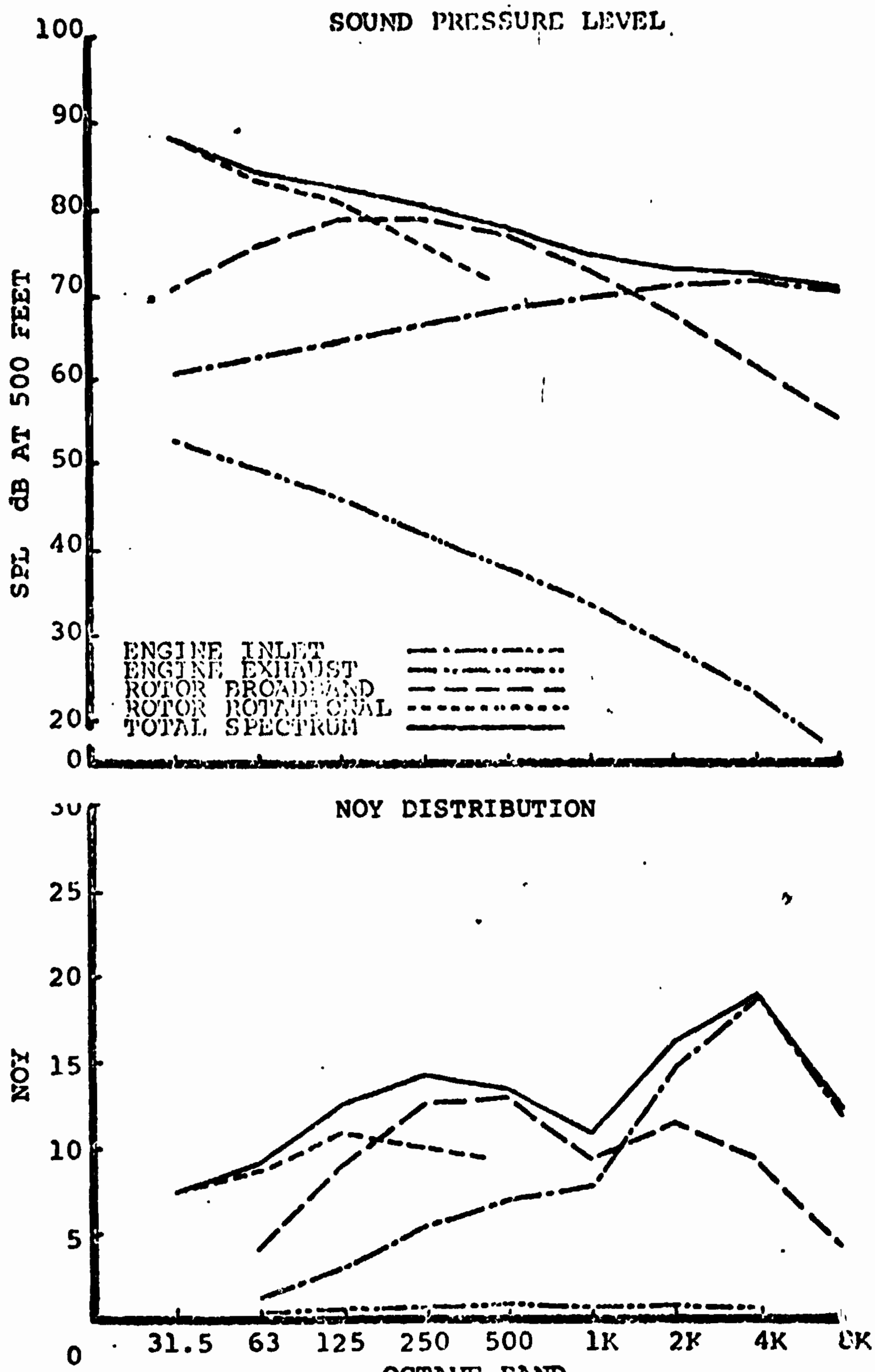
HELICOPTER HOVER NOISE PSECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 750, W/A = 6, PNdB = 96.9

Figure 2.7f. Tandem Helicopter - Tipspeed and Disc Loading Trade, 100 Passengers. Altitude = 5,000 Feet.



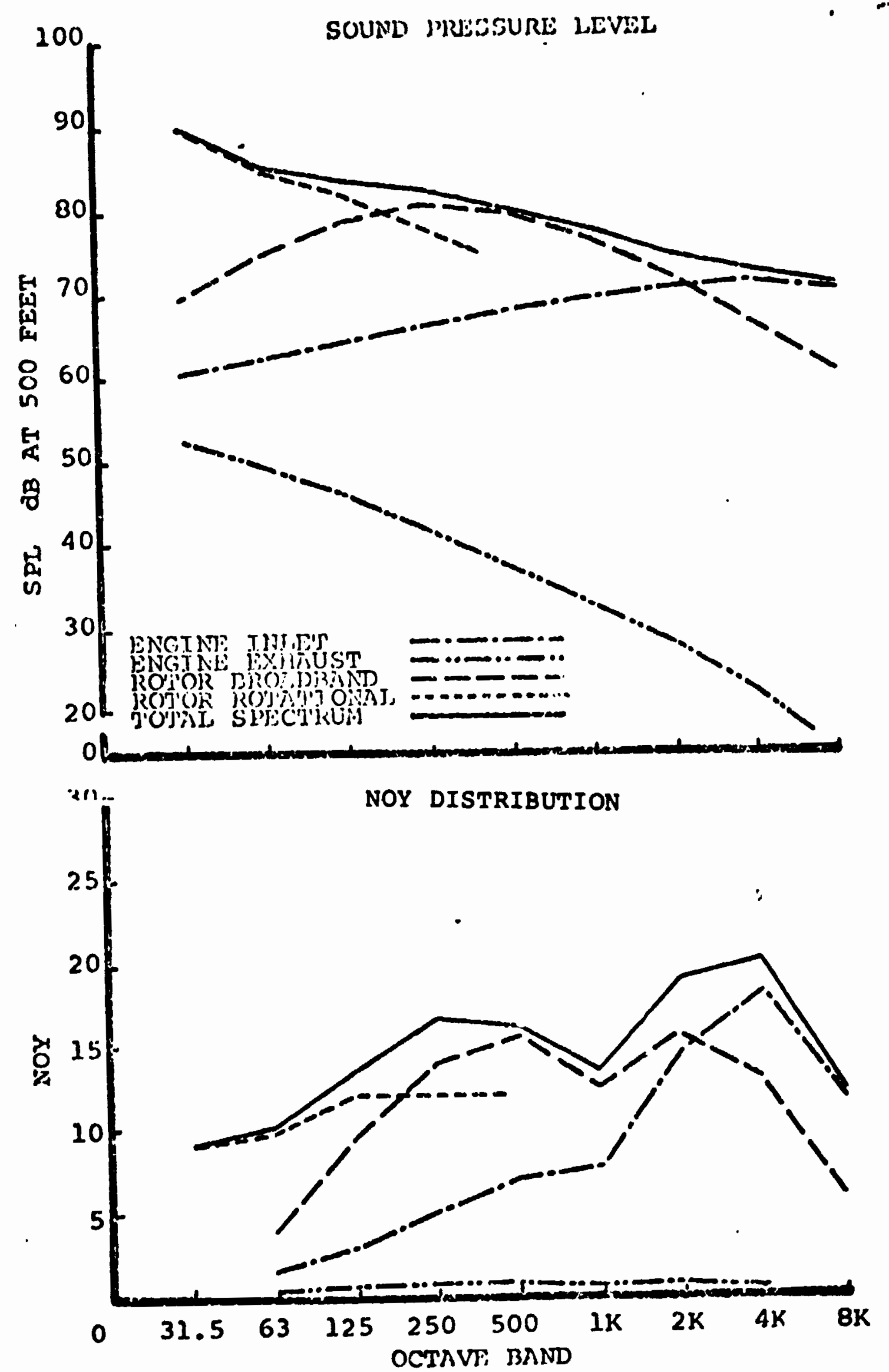
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 800, W/A = 6, PNdB = 98.4

Figure 2.7g. Tandem Helicopter - Tipspeed and Disc Loading Trade, 100 Passengers. Altitude = 5,000 Feet.



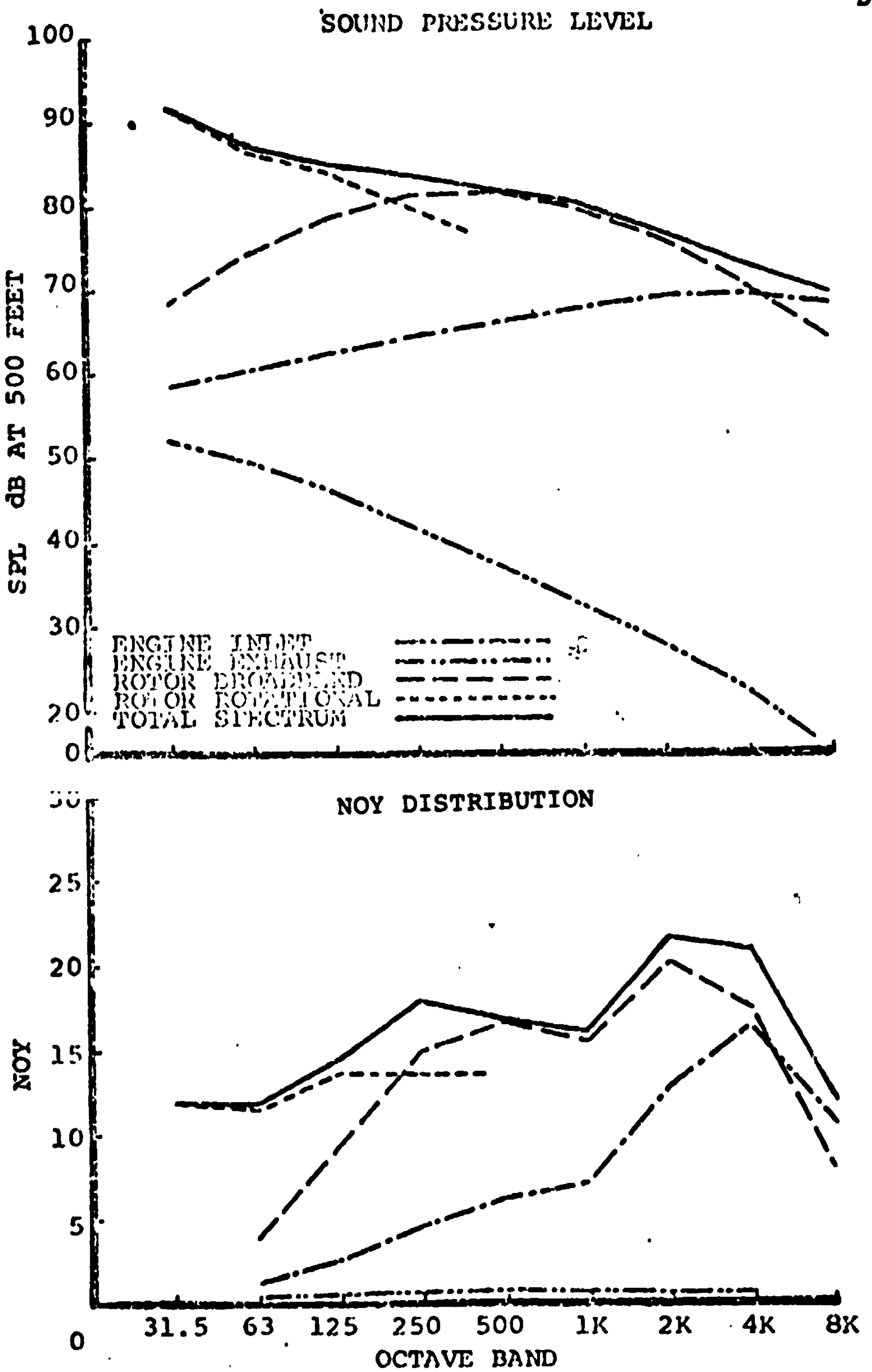
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 700, W/A = 8, PNdB = 95.9

Figure 2.7h. Tandem Helicopter - Tipspeed and Disc Loading Trade. 100 Passengers. Altitude = 5,000 Feet.



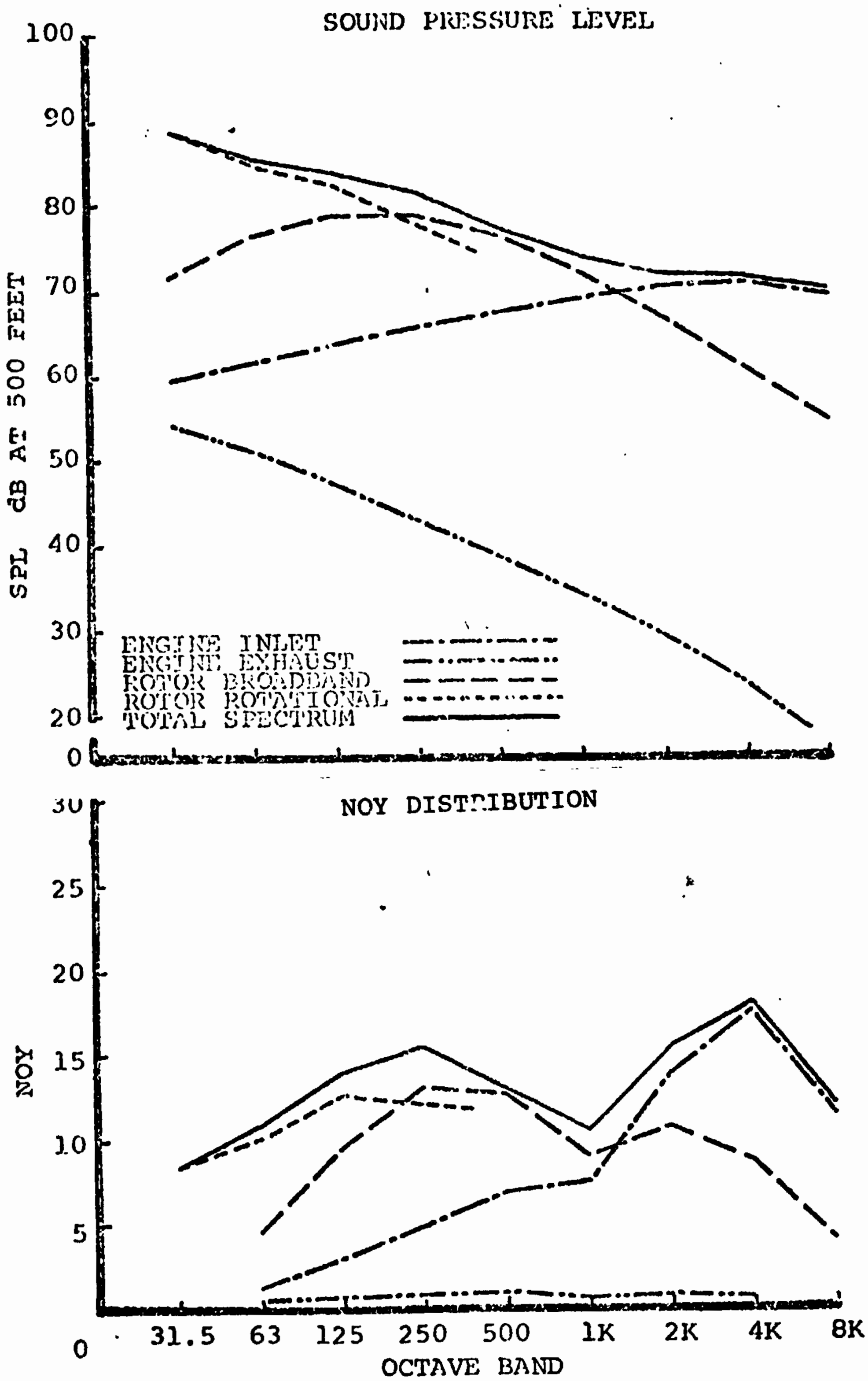
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 750, W/A = 8, PNdB = 97.4

Figure 2.7i. Tandem Helicopter - Tipspeed and Disc Loading Trade. 100 Passengers. Altitude = 5,000 Feet.



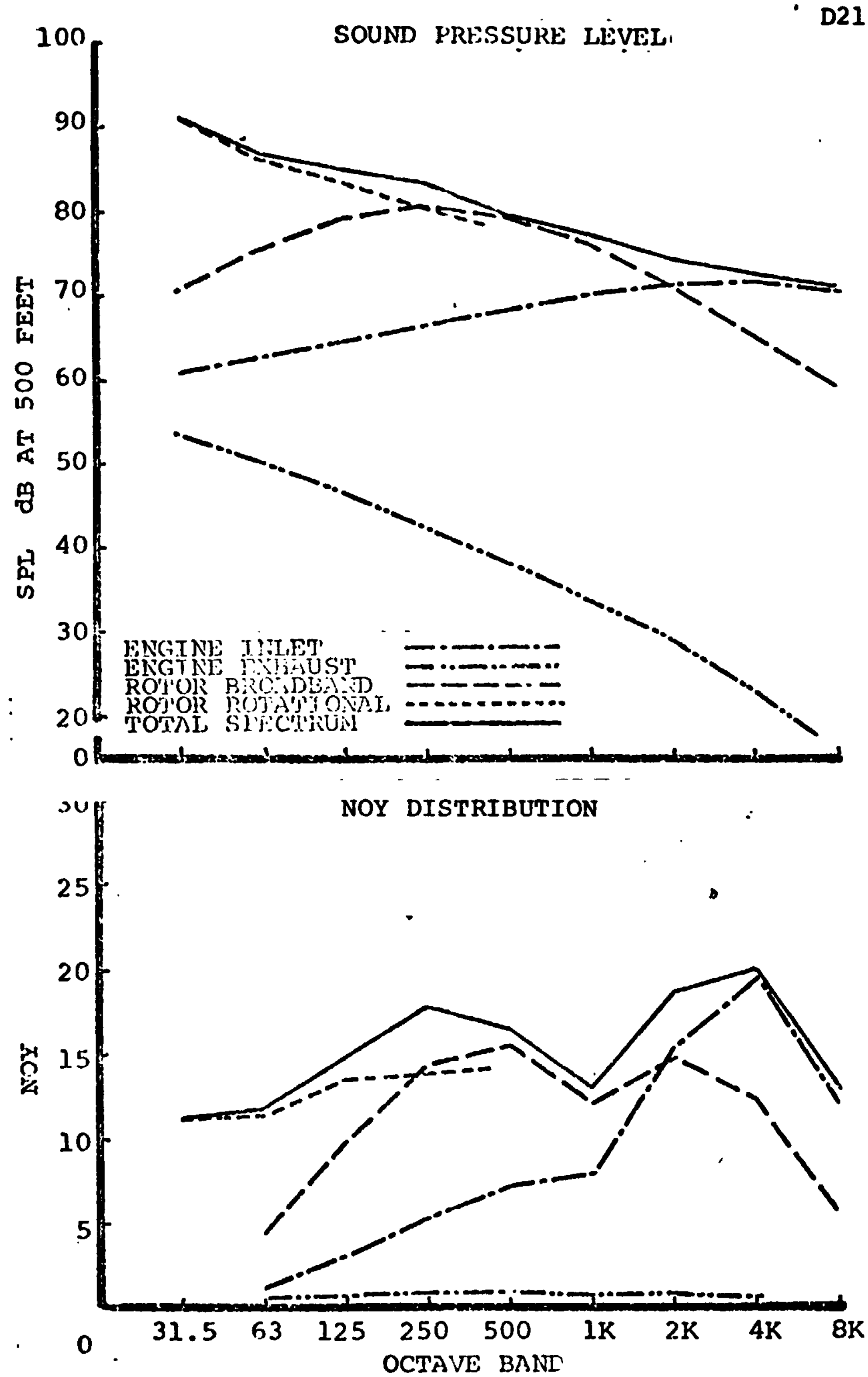
HELICOPTER HOVER NOISE PSECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 800, W/A = 8, PNdB = 98.7

Figure 2.7j. Tandem Helicopter - Tipspeed and Disc Loading Trade.
100 Passengers. Altitude = 5,000 Feet.



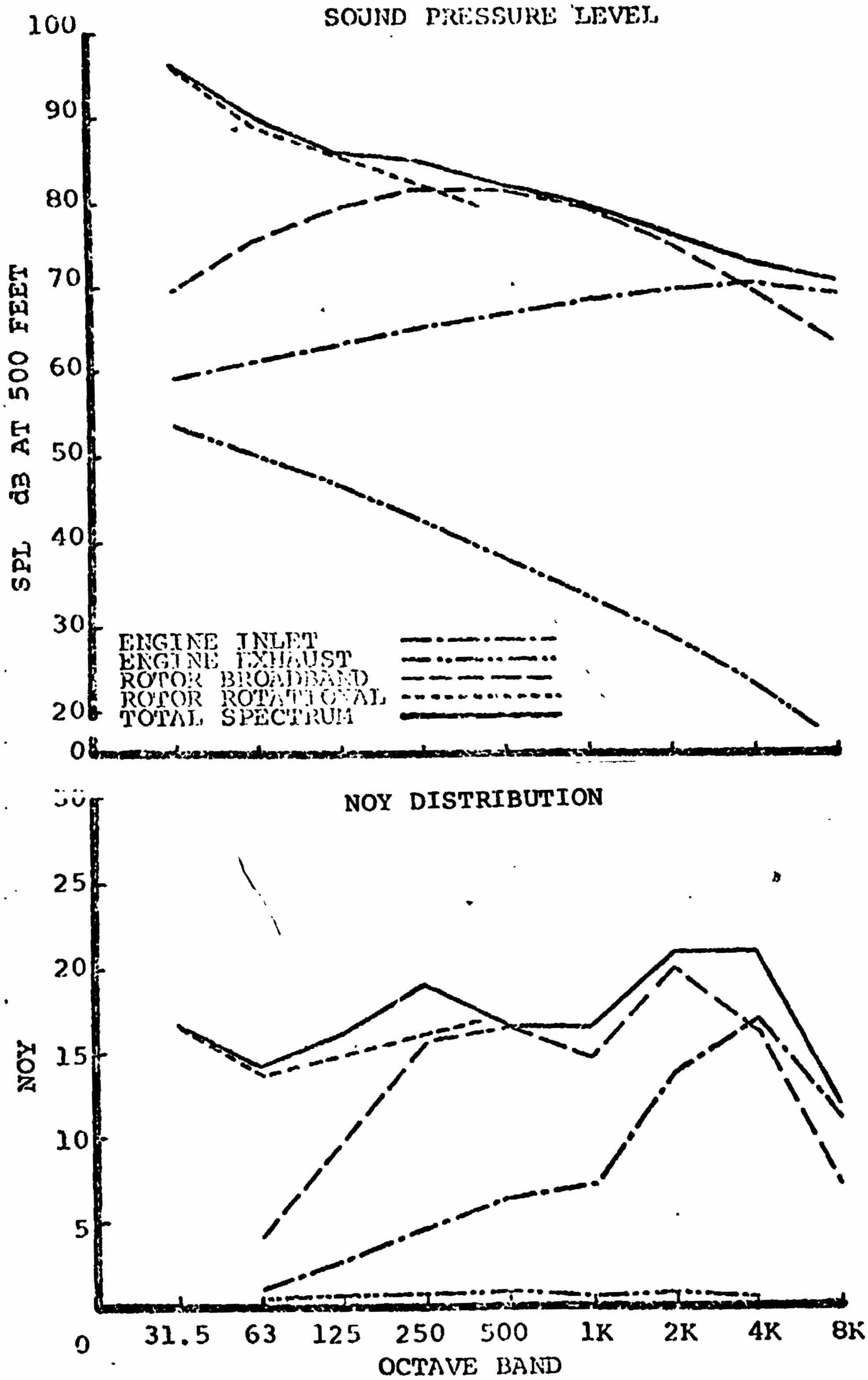
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 700, W/A = 10, PNdB = 95.9

Figure 2.7k. Tandem Helicopter - Tipspeed and Disc Loading Trade, 100 Passengers. Altitude = 5,000 Feet.



HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 750, W/A = 10, PNdB = 97.9

Figure 2.71. Tandem Helicopter - Tipspeed and Disc Loading Trade. 100 Passengers. Altitude = 5,000 Feet.



HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 800, W/A = 10, PNdB = 99.2

Figure 2.7m. Tandem Helicopter - Tipspeed and Disc Loading Trade. 100 Passengers. Altitude = 5,000 Feet.

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OF POOR QUALITY

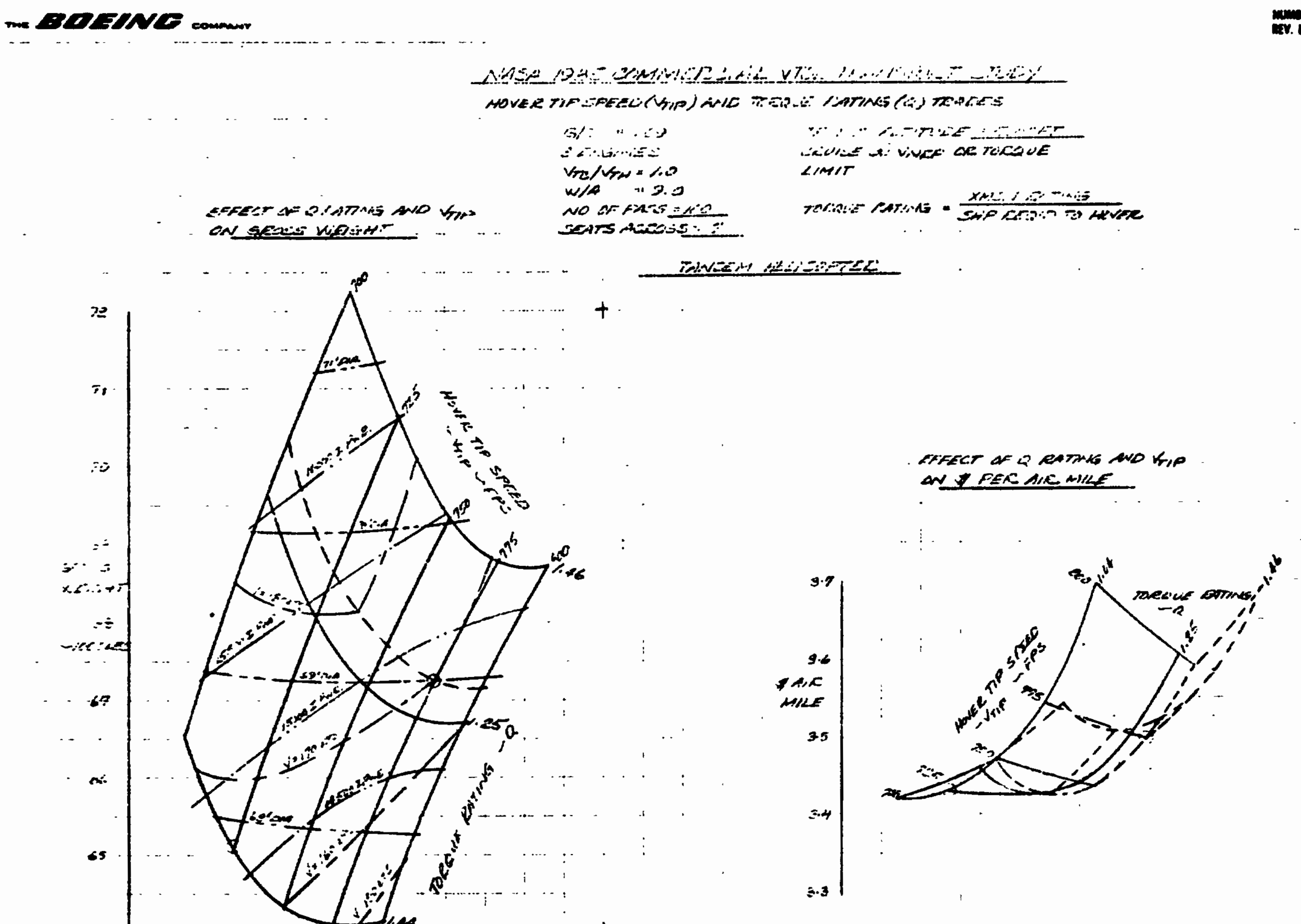


Figure 2.8a. Tandem Helicopter Transmission Rating and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

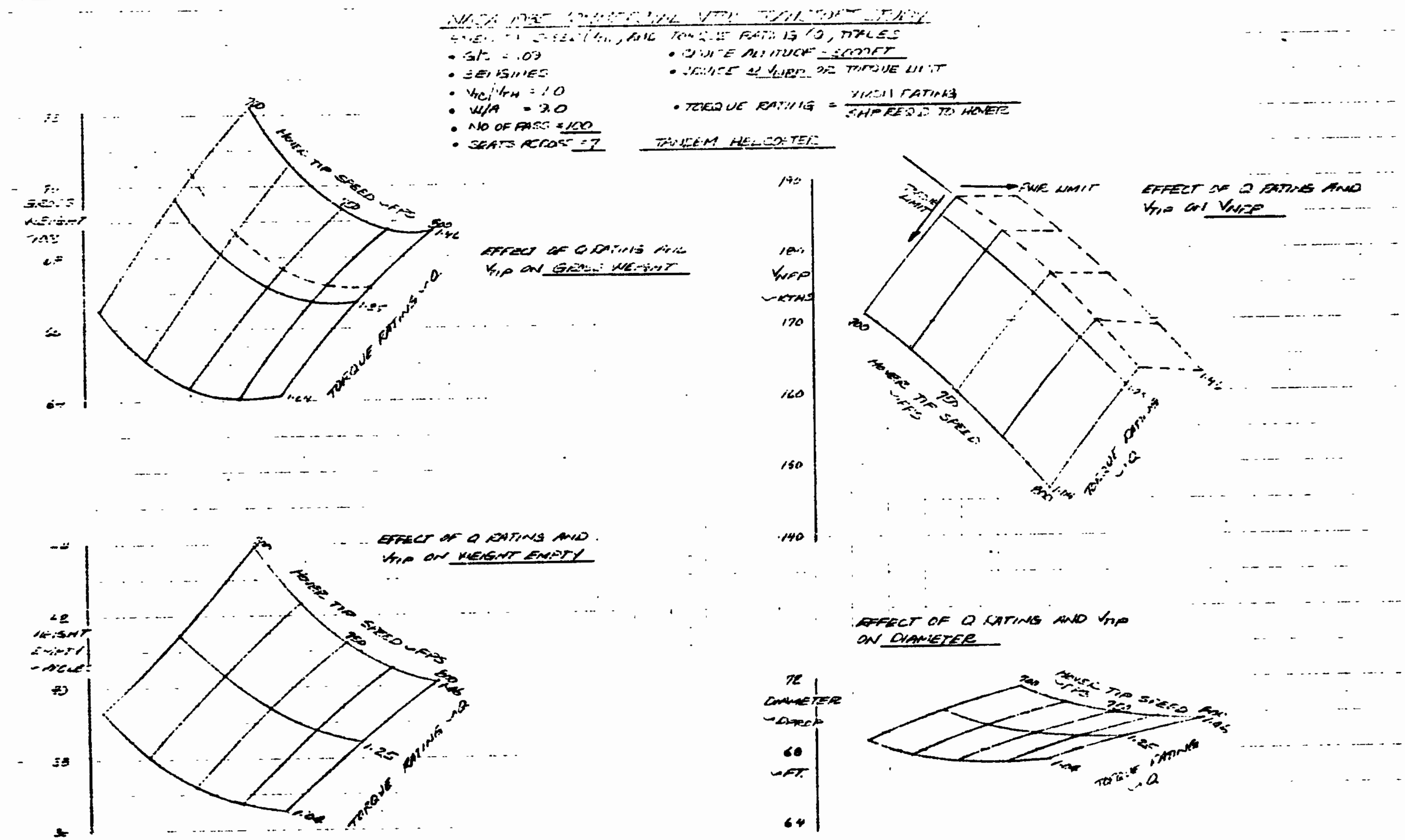


Figure 2.8b. Tandem Helicopter Transmission Rating and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

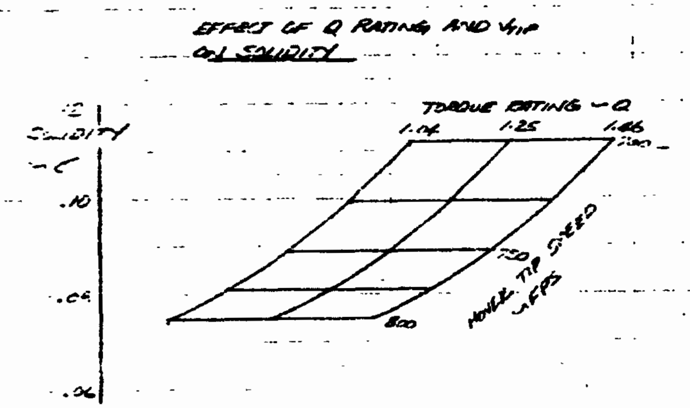
NASA 1980 COMMERCIAL VTOL TRANSPORT STUDY

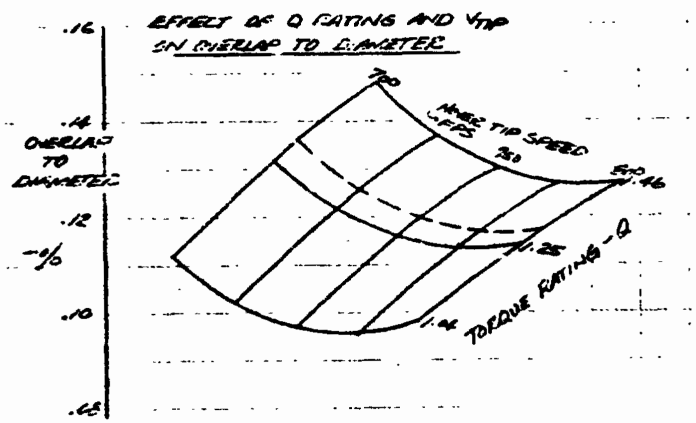
HOVER TIP SPEED (V_{TIP}) AND TORQUE RATINGS (Q) TRADES

- S/C = .09
- 2 ENGINES
- V_{TC}/V_{TH} = 1.0
- W/A = 9.0
- NO. OF PASS = 100
- SEATS ABREAST = 7

- CRUISE ALTITUDE = 5000 FT.
- CRUISE @ V_{NRP} OR TORQUE LIMIT
- TORQUE RATING = $\frac{\text{XMSN RATING}}{\text{SHP REQ'D TO HOVER}}$

TANDEM HELICOPTER





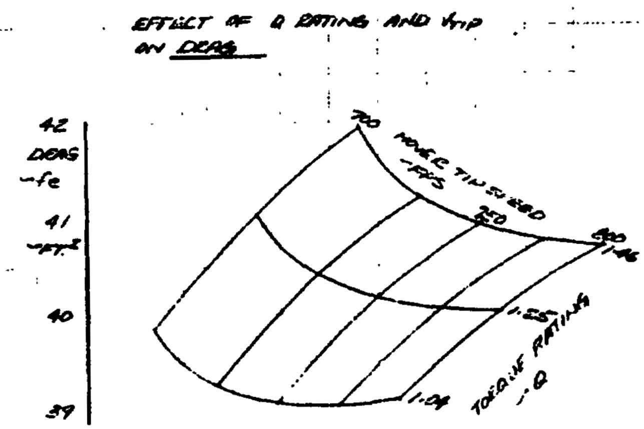


Figure 2.8c. Tandem Helicopter Transmission Rating and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

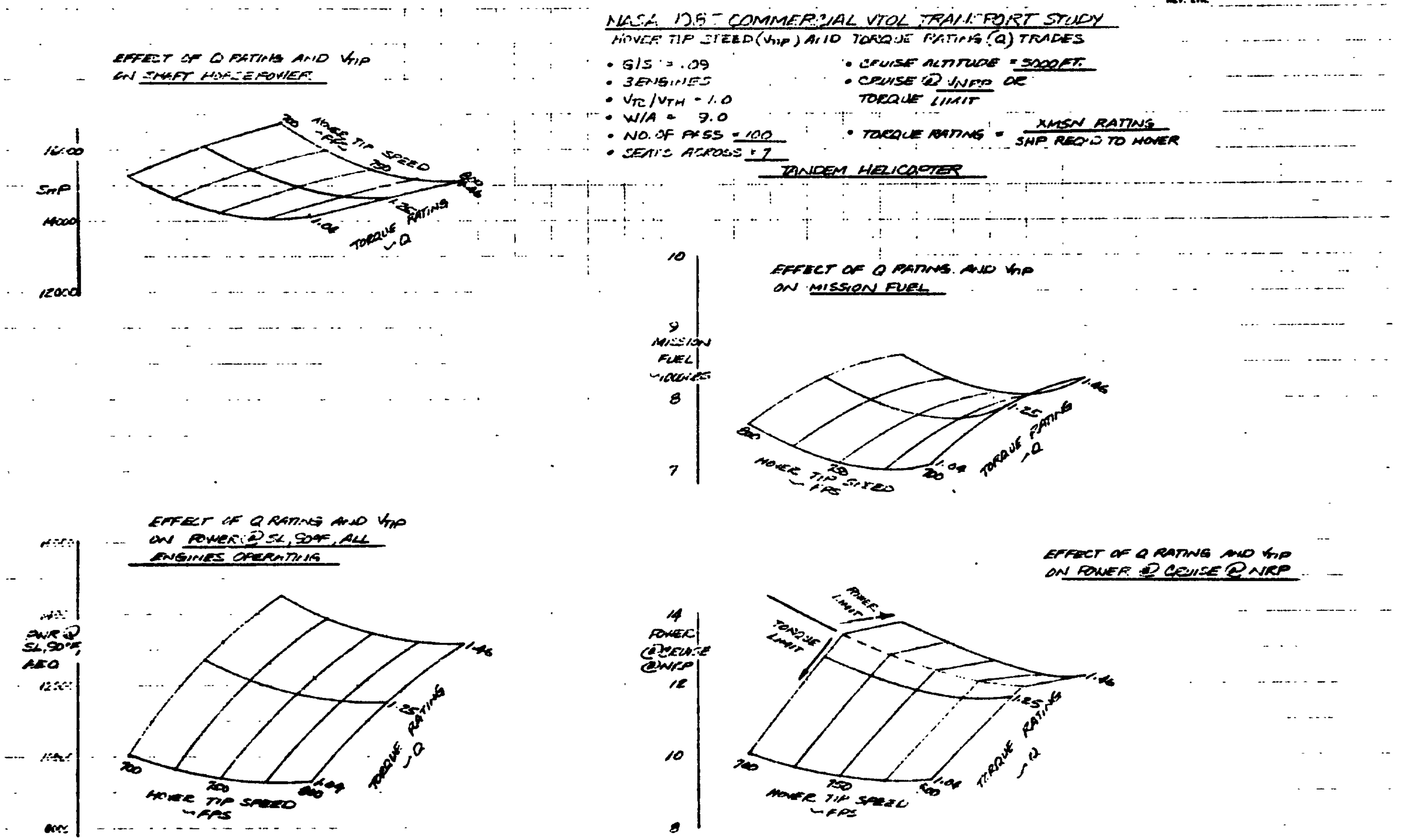


Figure 2.8d. Tandem Helicopter Transmission Rating and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

NASA 1985 COMMERCIAL VTOL TRANS. DEF. STUDY

ROTOR TIP SPEED (V_{TIP}) AND TORQUE RATING (Q) TRADES

S/S = .09
2 ENGINES
V_{TC}/V_{TH} = 1.0
W/A = 9.0
NO OF PASS = 100
SEATS ACROSS = 2

CRUISE ALTITUDE = 5000 FT.
CRUISE @ V_{MCP} OR TORQUE LIMIT

TORQUE RATING = THRUST RATING / 3HP REQ'D TO HOVER

TANDEM HELICOPTER

EFFECT OF Q RATING AND
V_{TIP} ¢/AIR MILE

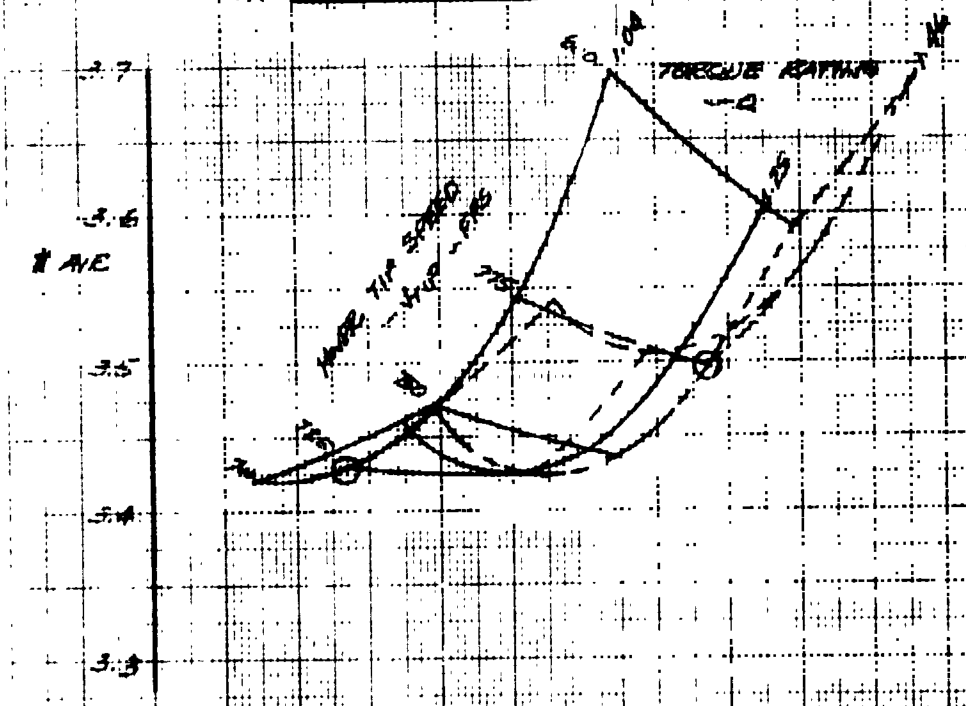
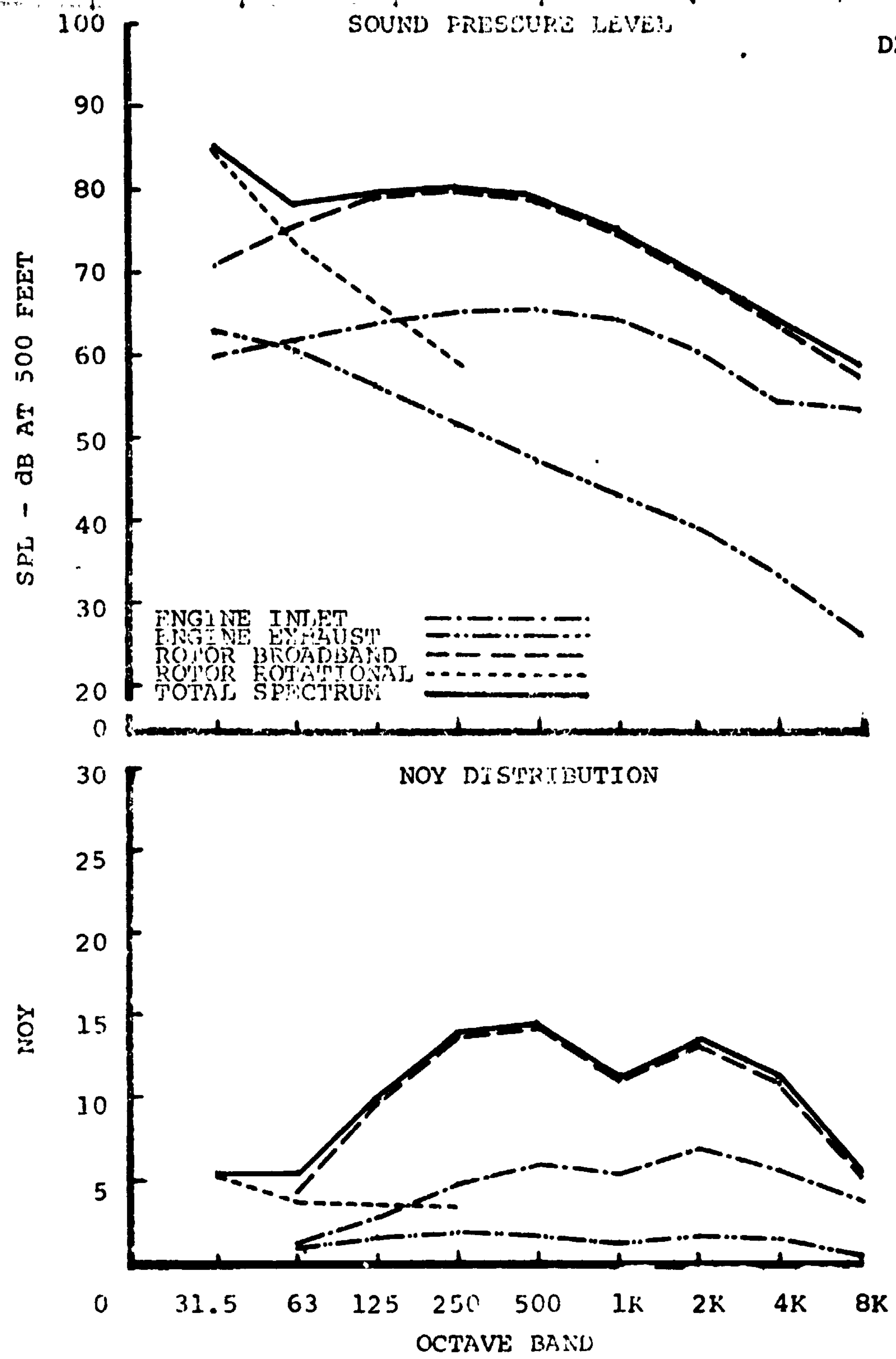


Figure 2.8e. Tandem Helicopter Transmission Rating and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 725, SIGMA = .099, CASE = 1, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 92.3

Figure 2.8f. Tandem Helicopter Transmission Rating and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

2.2 TREND DATA FOR NOISE DERIVATIVE - TANDEM HELICOPTER DESIGNS

One of the objectives of the design study was to examine the impact of external noise design criteria on the aircraft design and performance parameters. To do this two further tandem helicopters were to be designed. One 5 PNdB more noisy than the baseline aircraft, and a second 5 PNdB less noisy than the baseline vehicle.

As described earlier the engine inlet noise was attenuated to ensure that the overall sound pressure level was set by rotor noise. Having done this the primary parameters available to the designer to influence noise are solidity, tipspeed and disc loading. Of these, tipspeed is by far the most powerful influence, followed by blade loading (solidity). Disc loading is a relatively insensitive parameter.

Figure 2.9b shows the variation of gross weight as a function of hover tipspeed and solidity ratio.

Solidity is referenced two ways on this carpet plot. The broken lines are constant values of rotor solidity (i.e., $\sigma = bc/\pi R$).

The solidity sizing factor is a factor applied to the solidity sizing criteria to obtain a parametric variation in blade loading.

Superimposed on this chart is a minimum solidity requirement to meet 1.25 g's at cruise speed with no stall flutter.

Figure 2.9a is the same data replotted including contours of direct operating cost and 500-foot sideline noise levels. The constant noise line labelled Δ0 PNdB is a family of aircraft

whose sideline noise is the same as the design point aircraft (92.3 PNdB). The other two constant noise level lines represent aircraft ± 5 PNdB from the baseline.

The contours of direct operating cost allows minimum cost vehicles to be selected. For the -5 PNdB the minimum DOC aircraft occurs at V_T = 605 feet per second and a solidity sizing factor of 0.88. This aircraft, however, violates the minimum solidity requirement to allow maneuver margin. The aircraft selected was defined by the intersection of the -5 PNdB line and the minimum solidity line giving a gross weight of 73,800 pounds.

A similar logic was applied to select the +5 PNdB aircraft and resulted in a design gross weight of 65,900 pounds.

The variation in the design details for this range of parametric aircraft are included in Figures 2.9e to 2.9f.

The noise derivative aircraft selected were subsequently refined and resized to give the design gross weights of 65,843 pounds for +5 PNdB and 74,227 pounds -5 PNdB.

The overall sound pressure level data for each of these parametric aircraft are shown in Figures 2.9h to 2.9z.

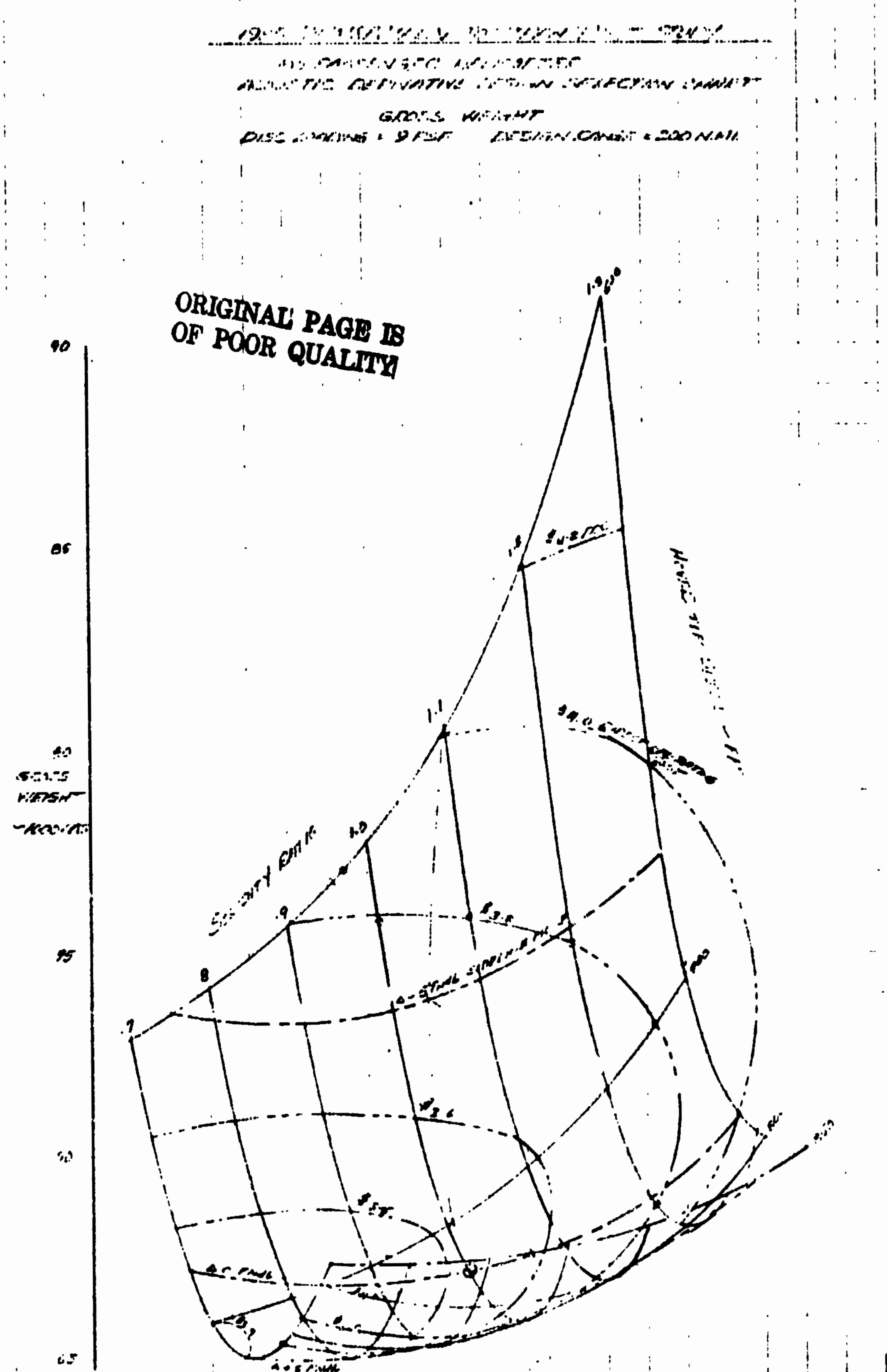


Figure 2.9a. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

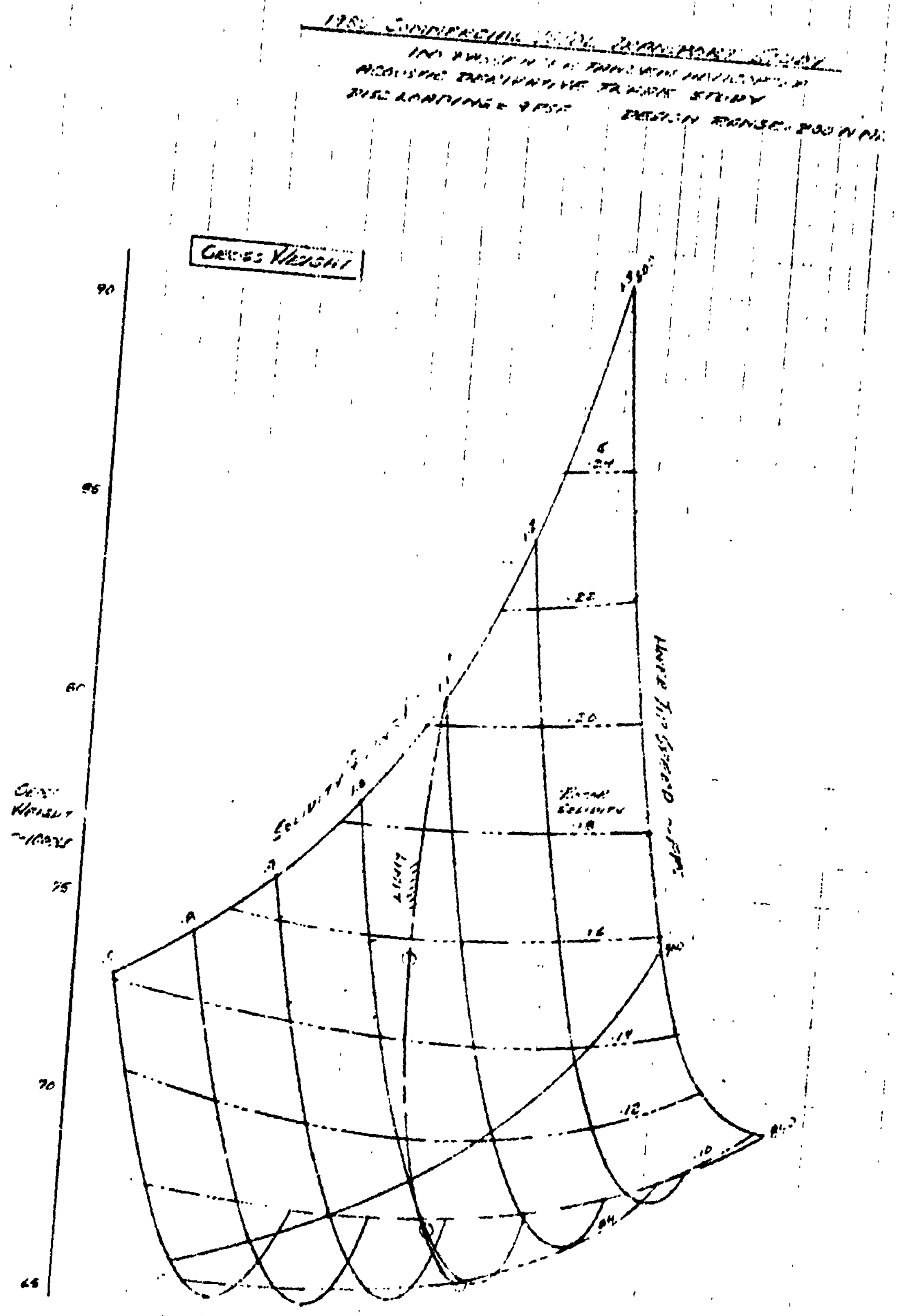


Figure 2.9b. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

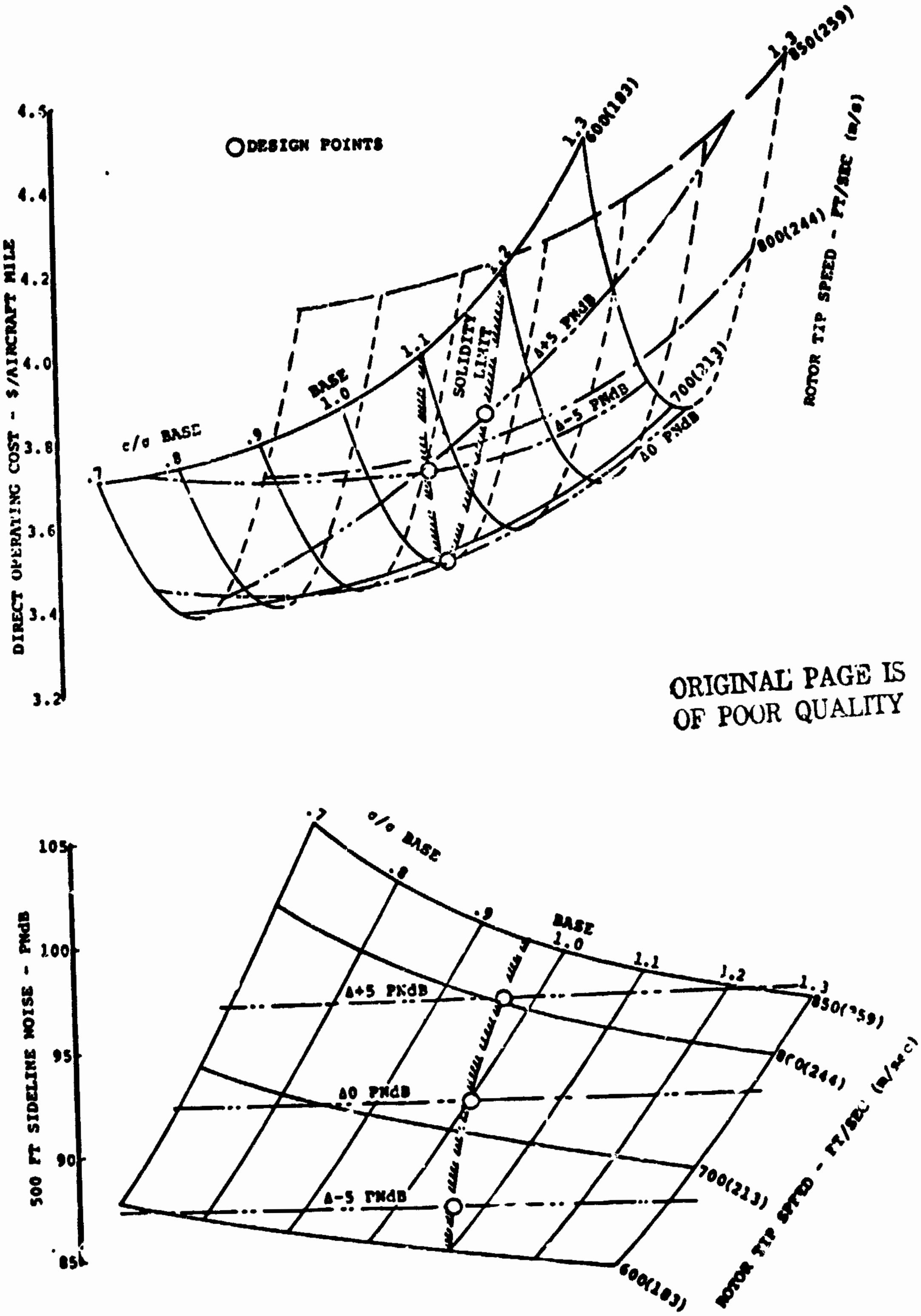


FIGURE 2.9C. TANDEM HELICOPTER - NOISE DERIVATIVE TRADE STUDY - 100 PASSENGERS. ALTITUDE = 5,000 FEET, DISC LOADING = 9 PSF.

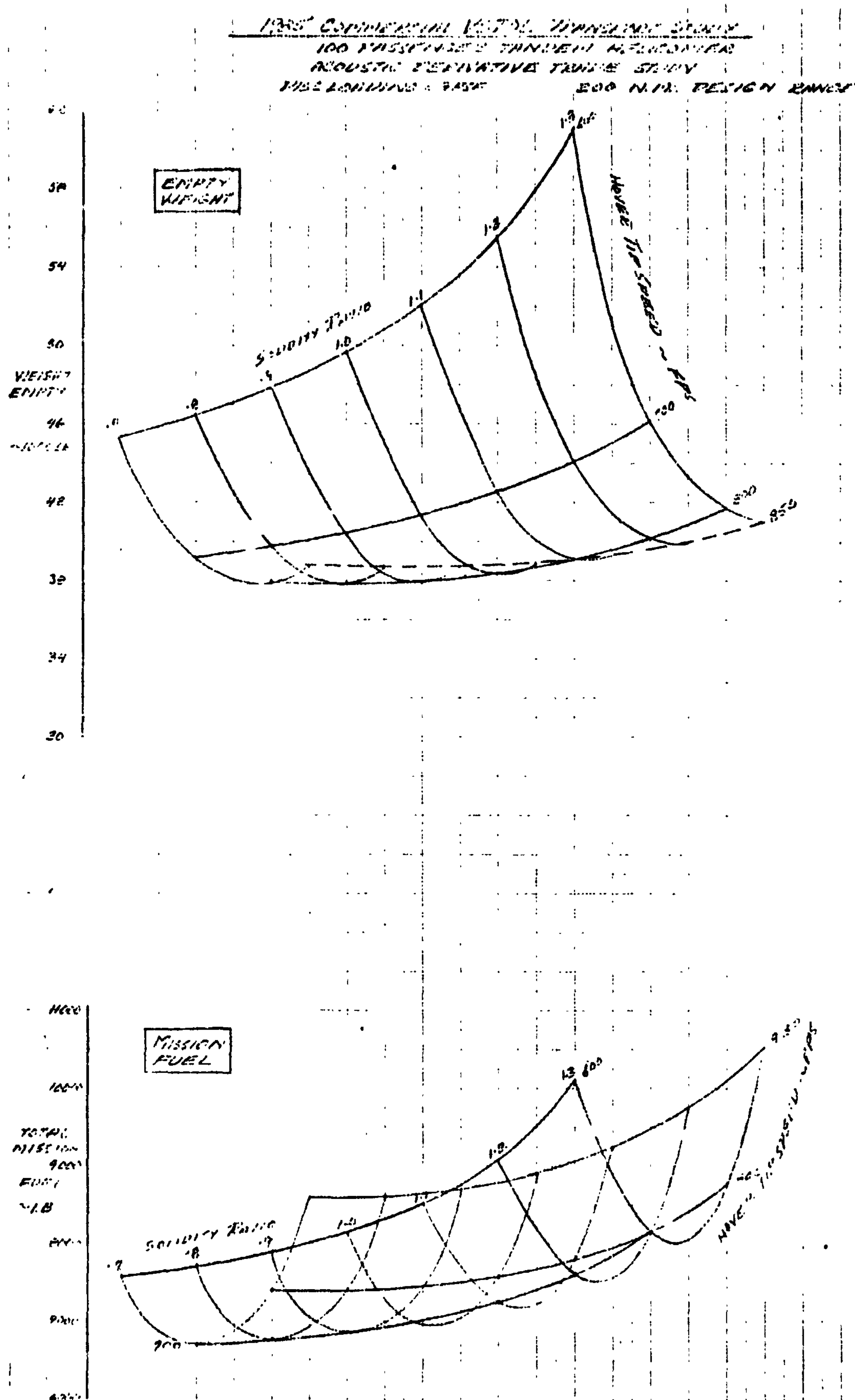


Figure 2.9d. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 feet. Disc Loading = 9 PSF.

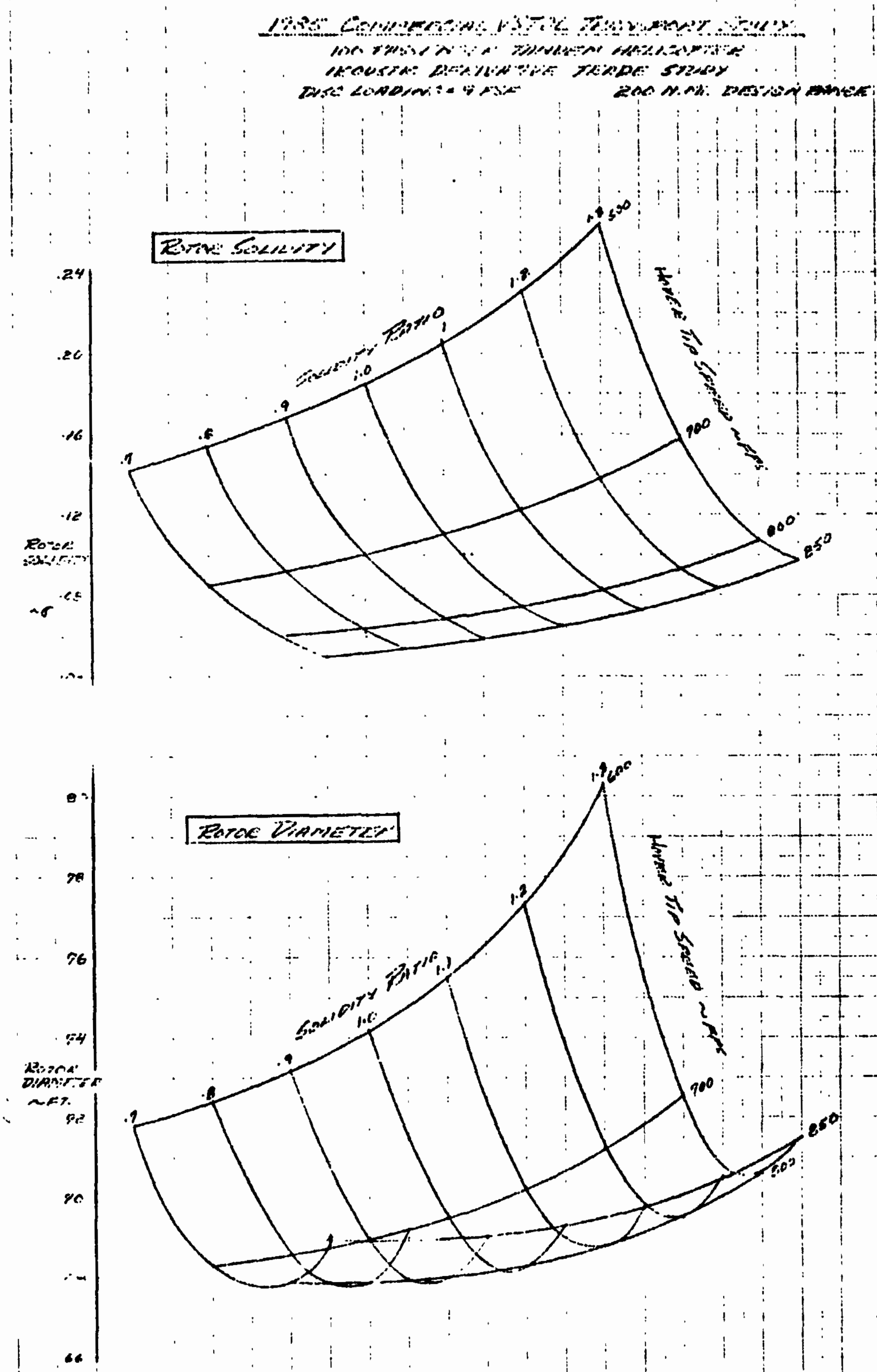


Figure 2.9a. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

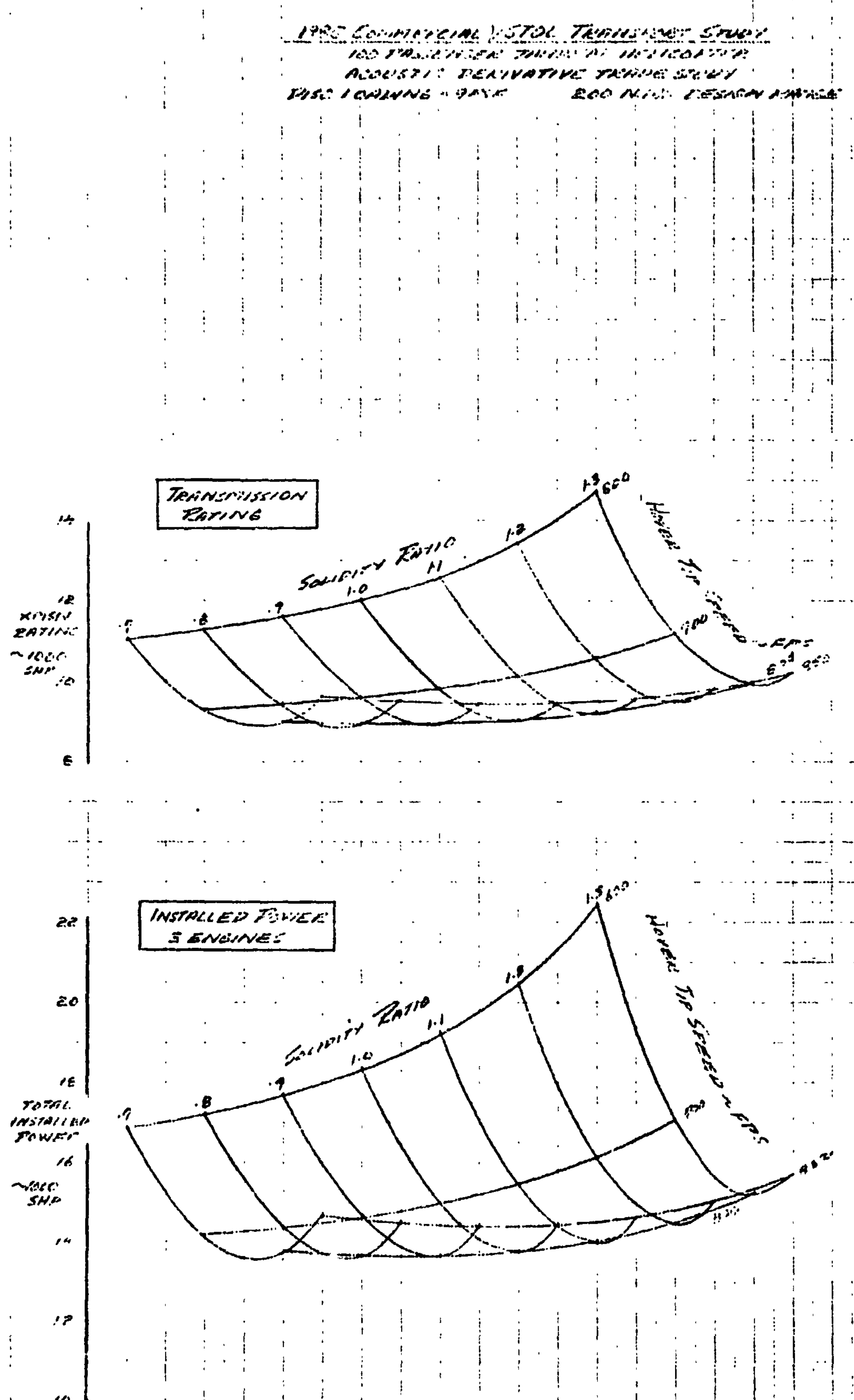


Figure 2.9f. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

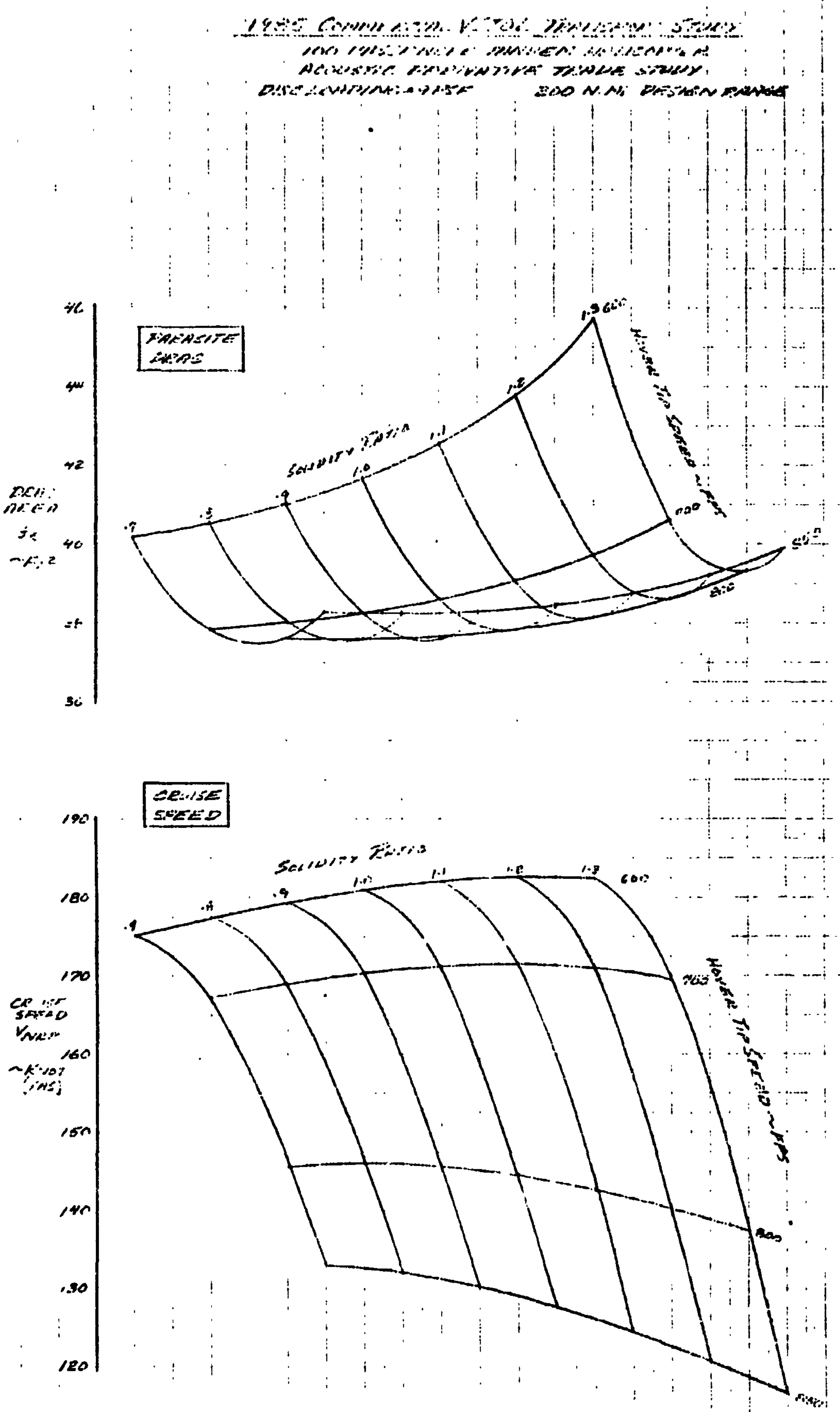
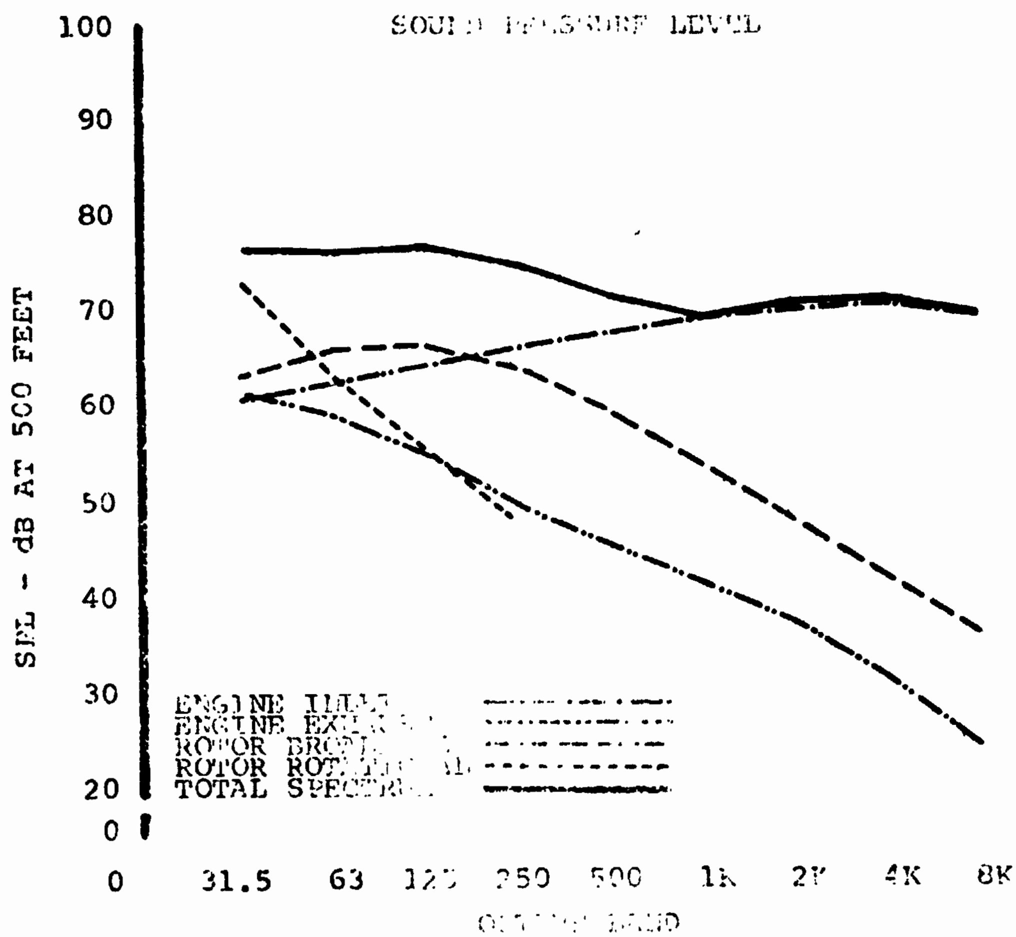
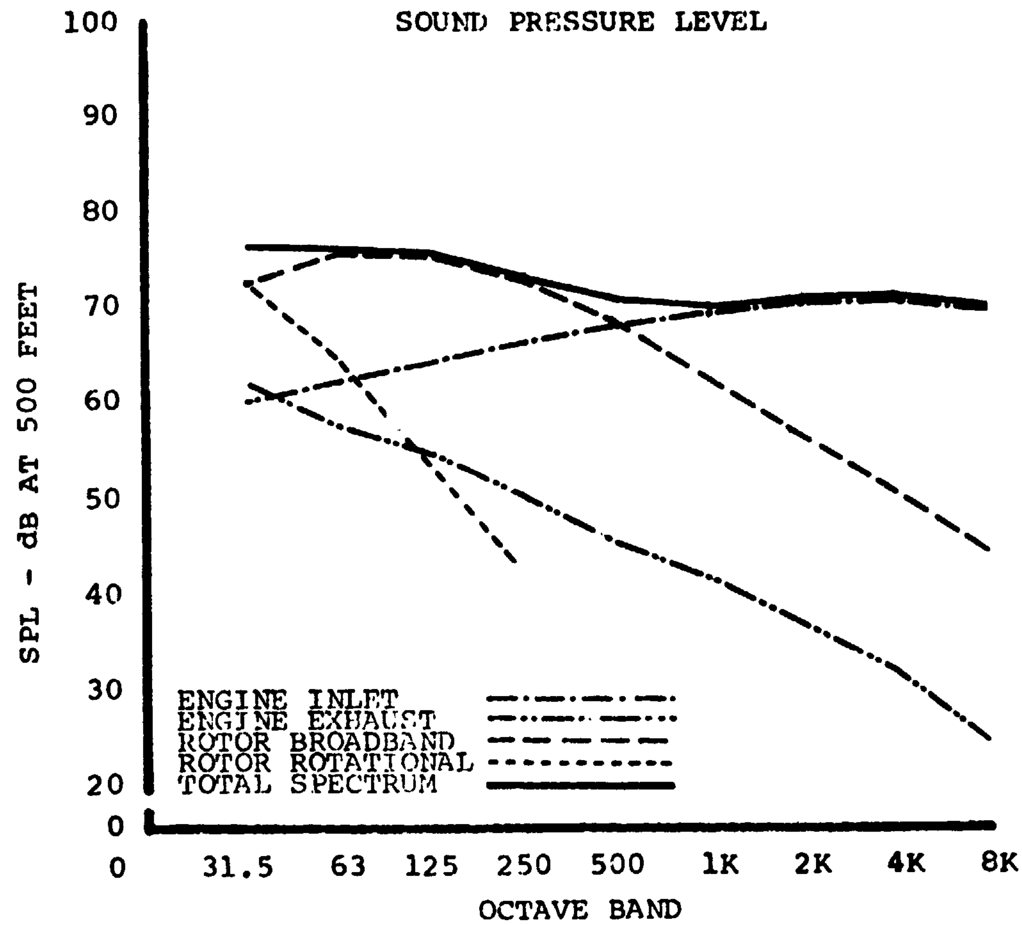


Figure 2.9g. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



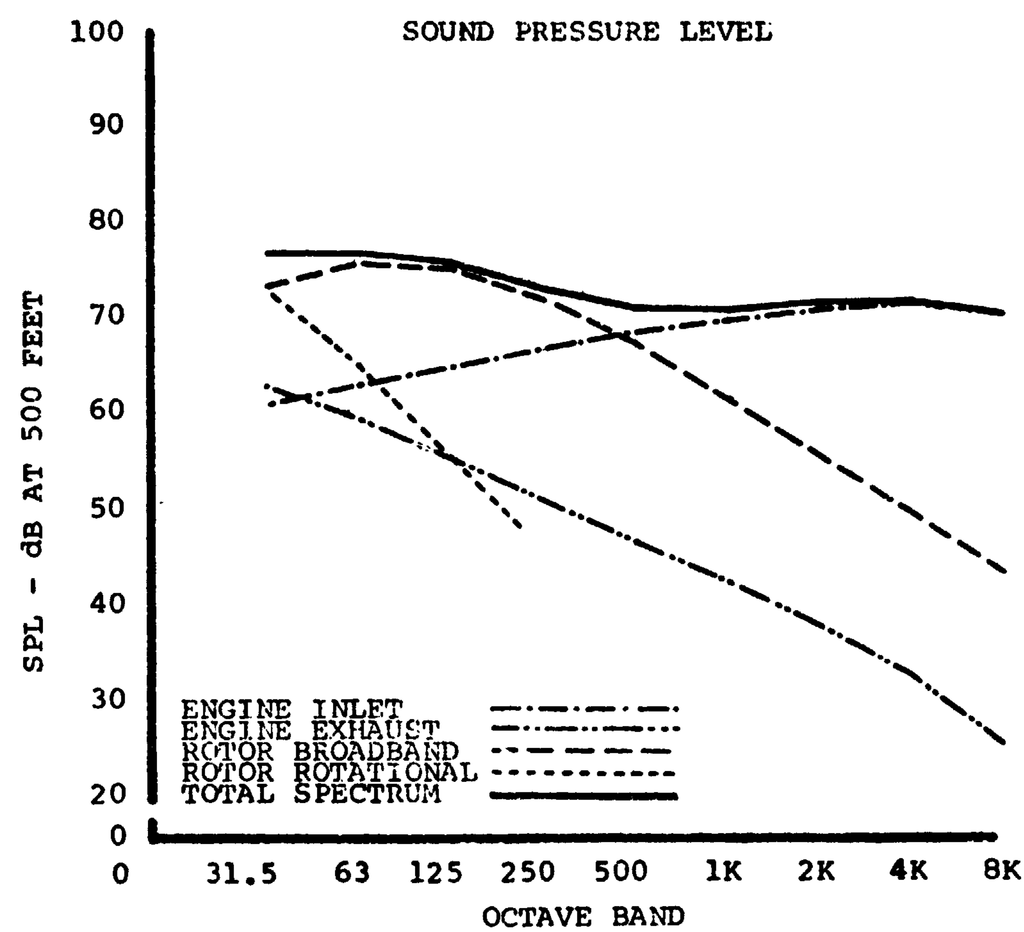
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .168, CASE = 10, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 92.8

Figure 2.9h. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



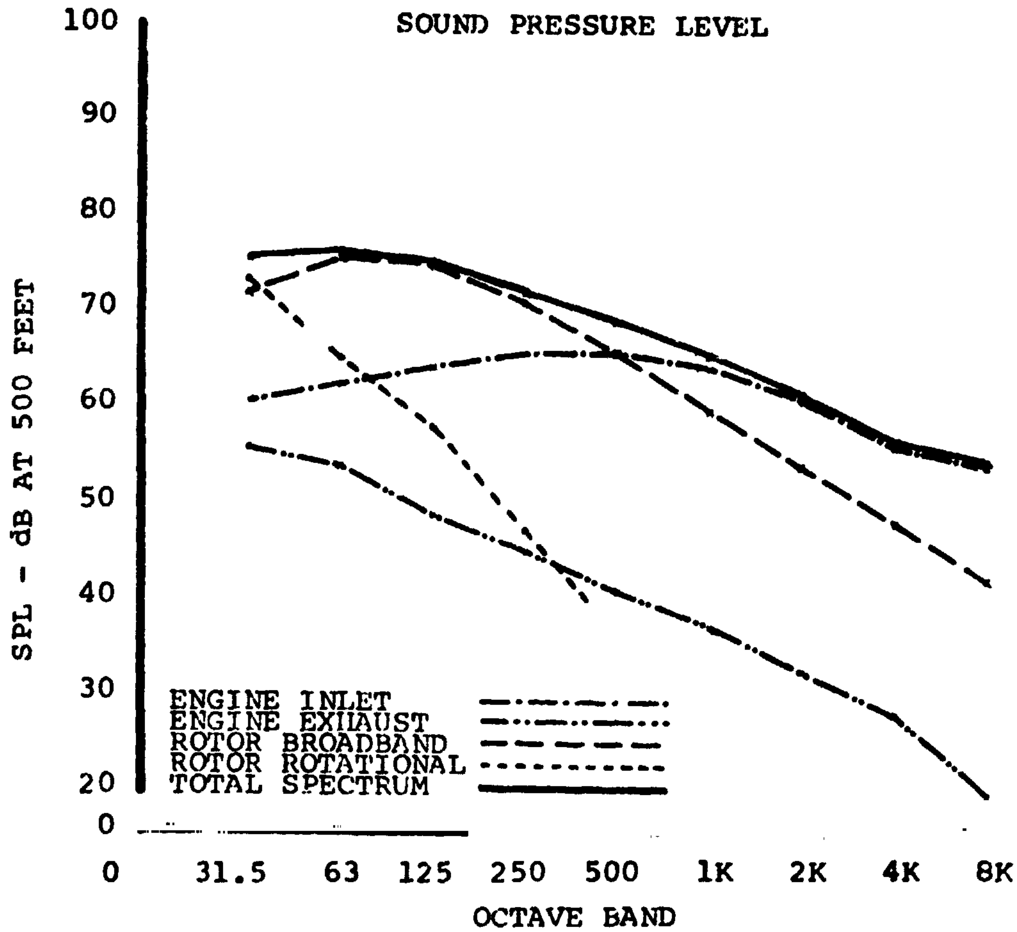
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .185, CASE = 8, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 92.9

Figure 2.9i. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



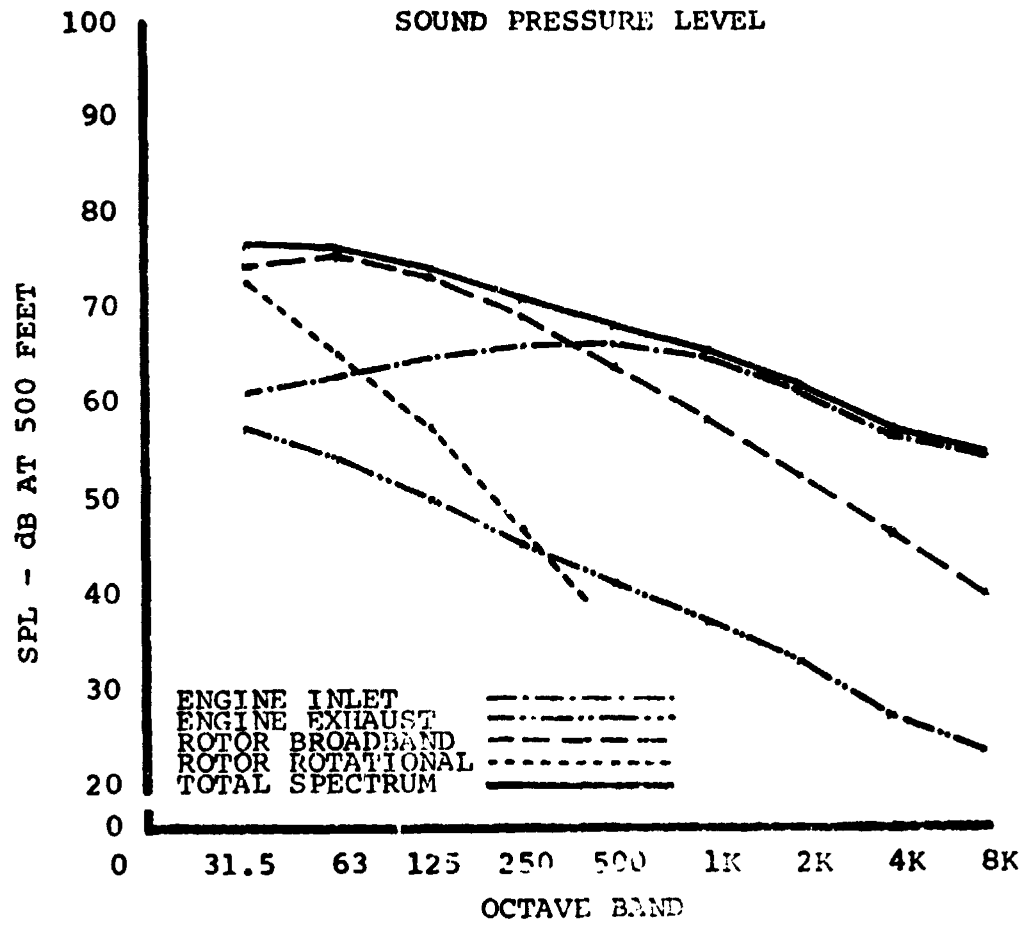
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .205, CASE = 9, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 92.8

Figure 2.9j. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



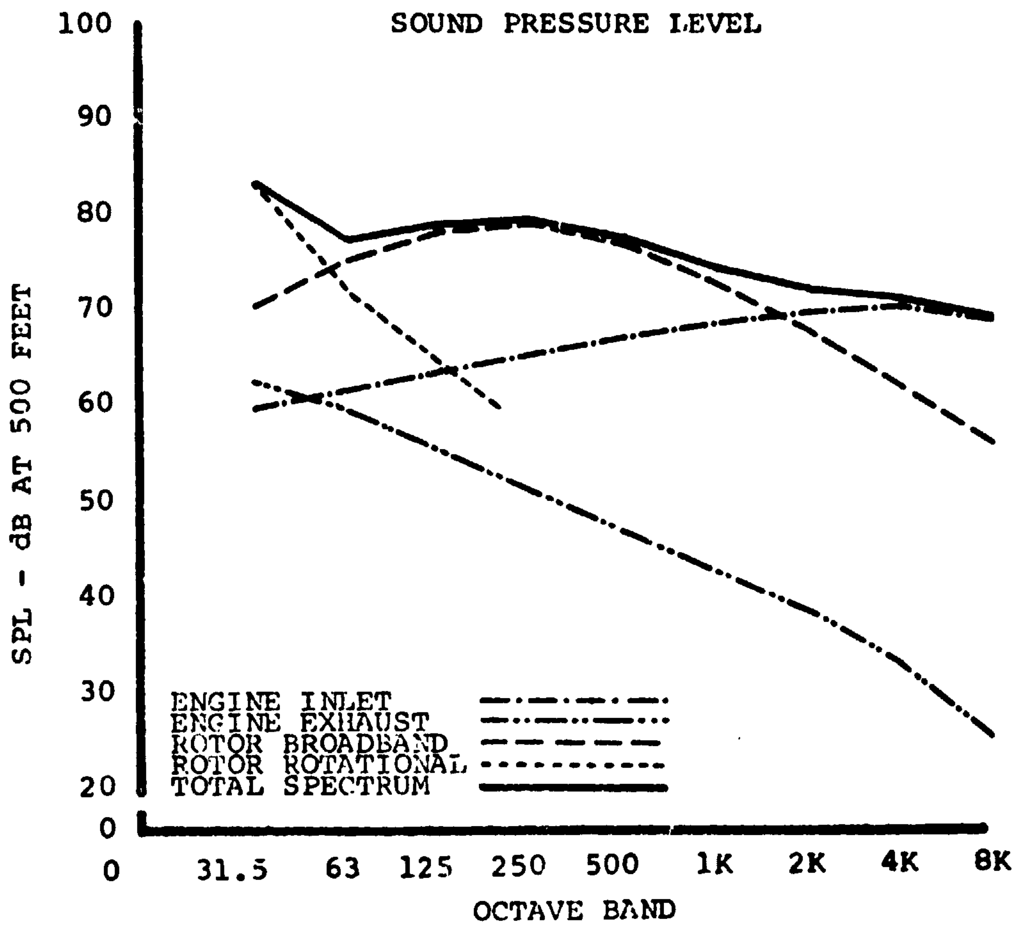
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .231, CASE = 17, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 84.3

Figure 2.9k. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



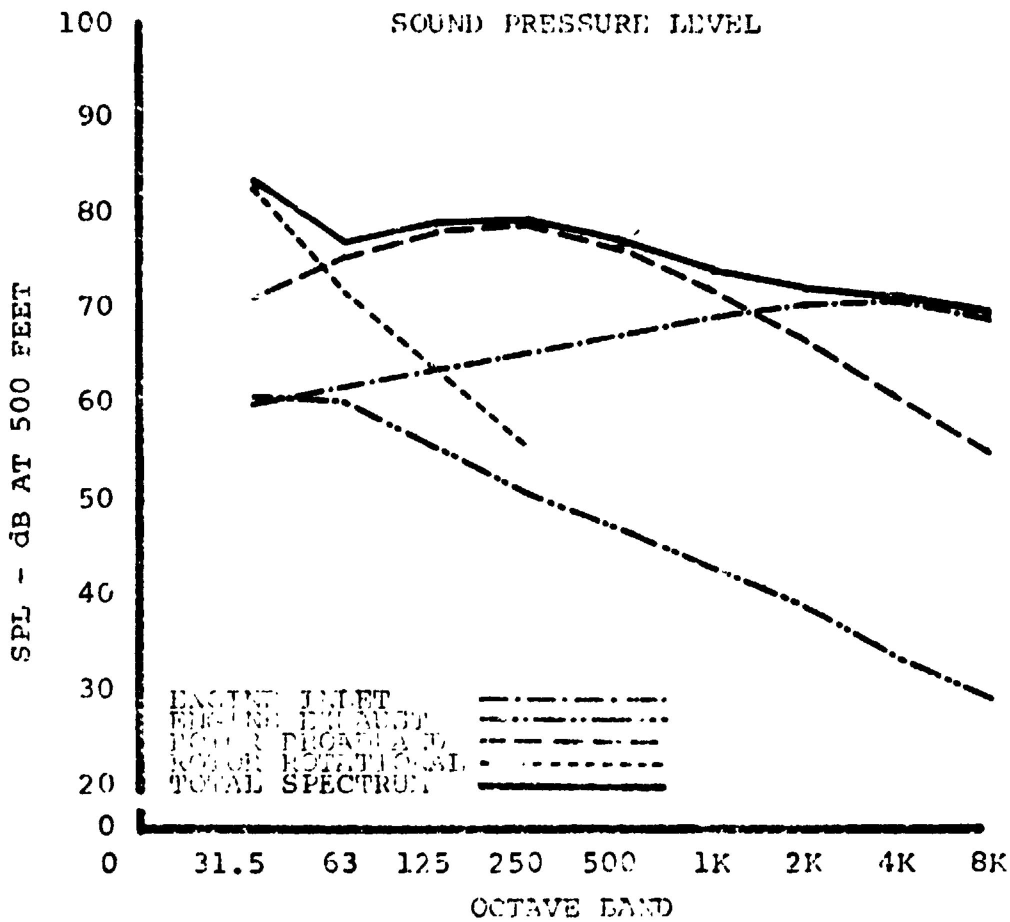
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .264, CASE = 18, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 84.1

Figure 2.91. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



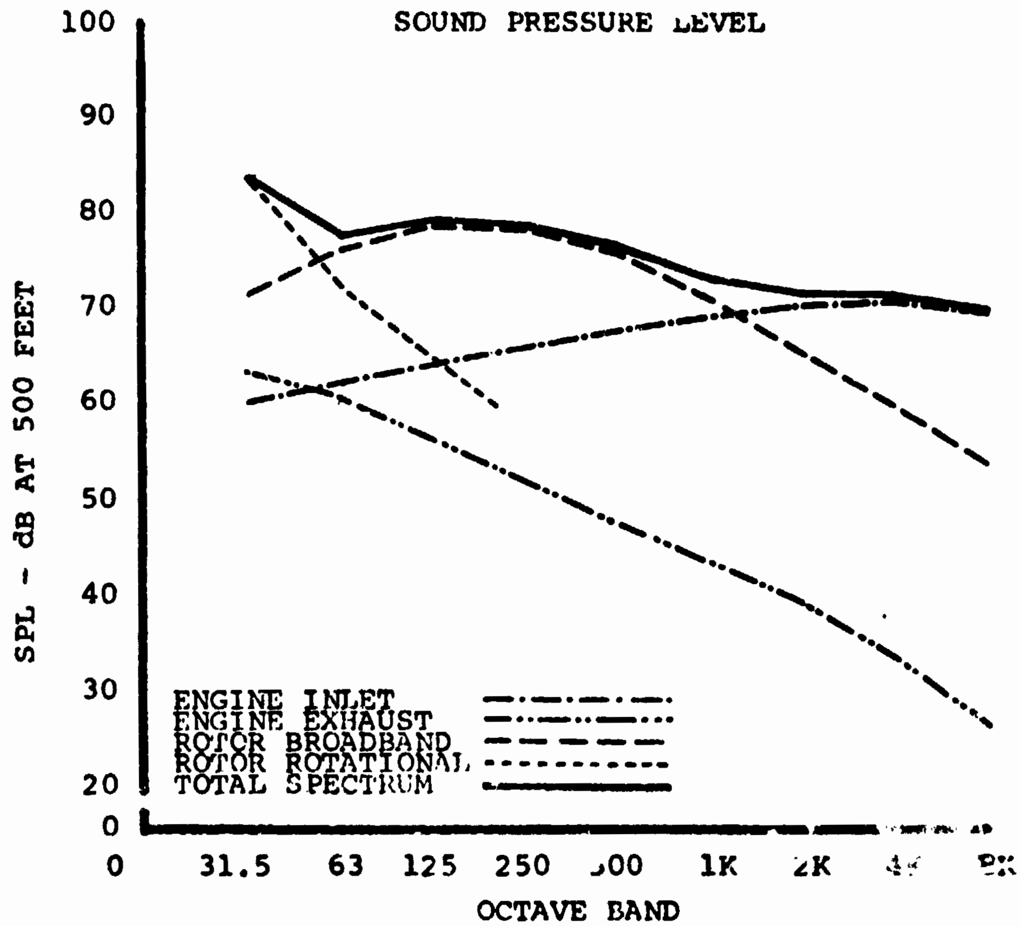
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 700, SIGMA = .101, CASE = 4, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 94.7

Figure 2.9m. **Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.**



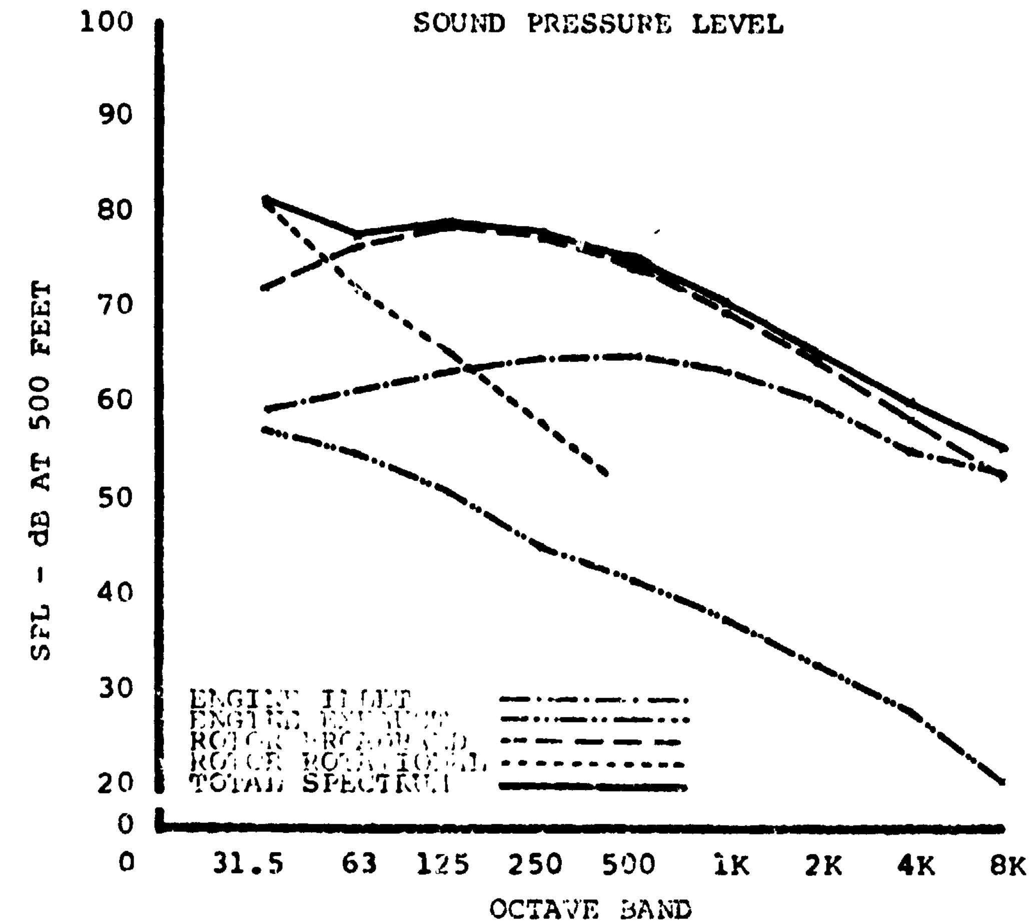
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 700, SIGMA = .111, CASE = 2, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 94.5

Figure 2.9n. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



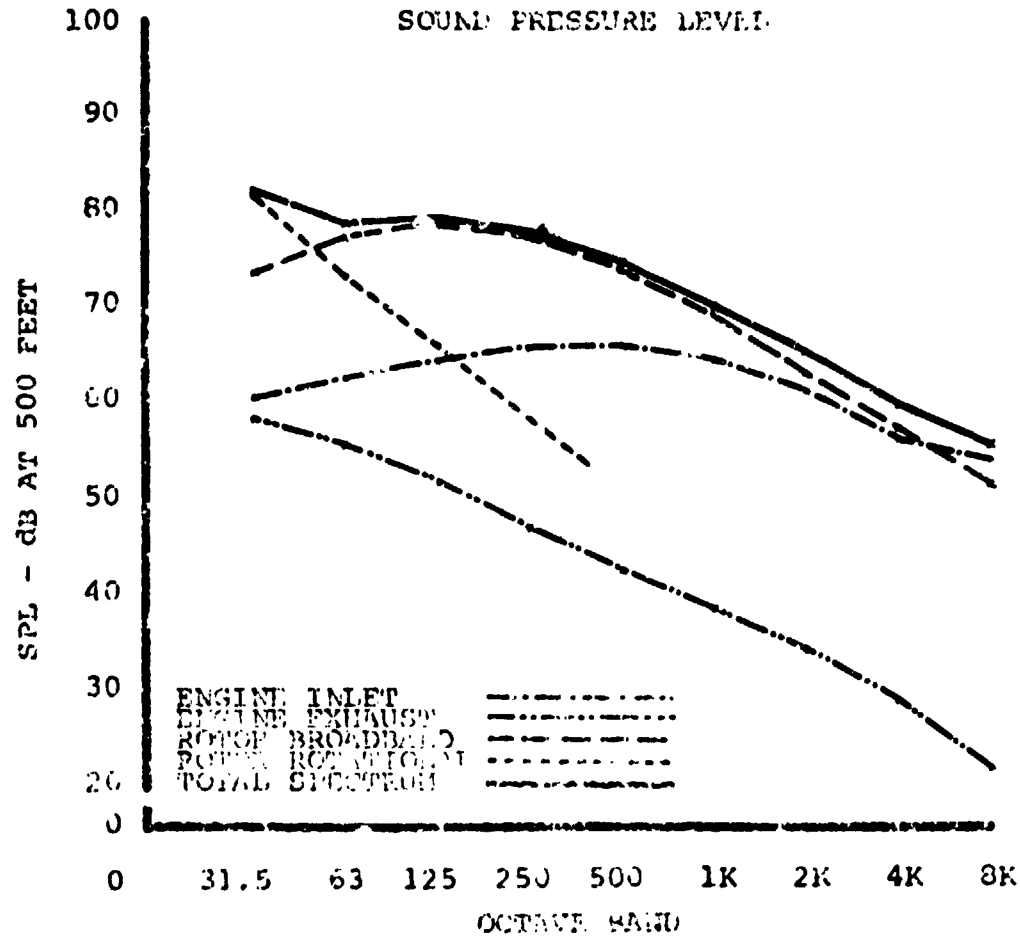
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100
PASSENGERS, VT = 700, SIGMA = .123, CASE = 3, WORST AZIMUTH,
AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 94.3

Figure 2.9o. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



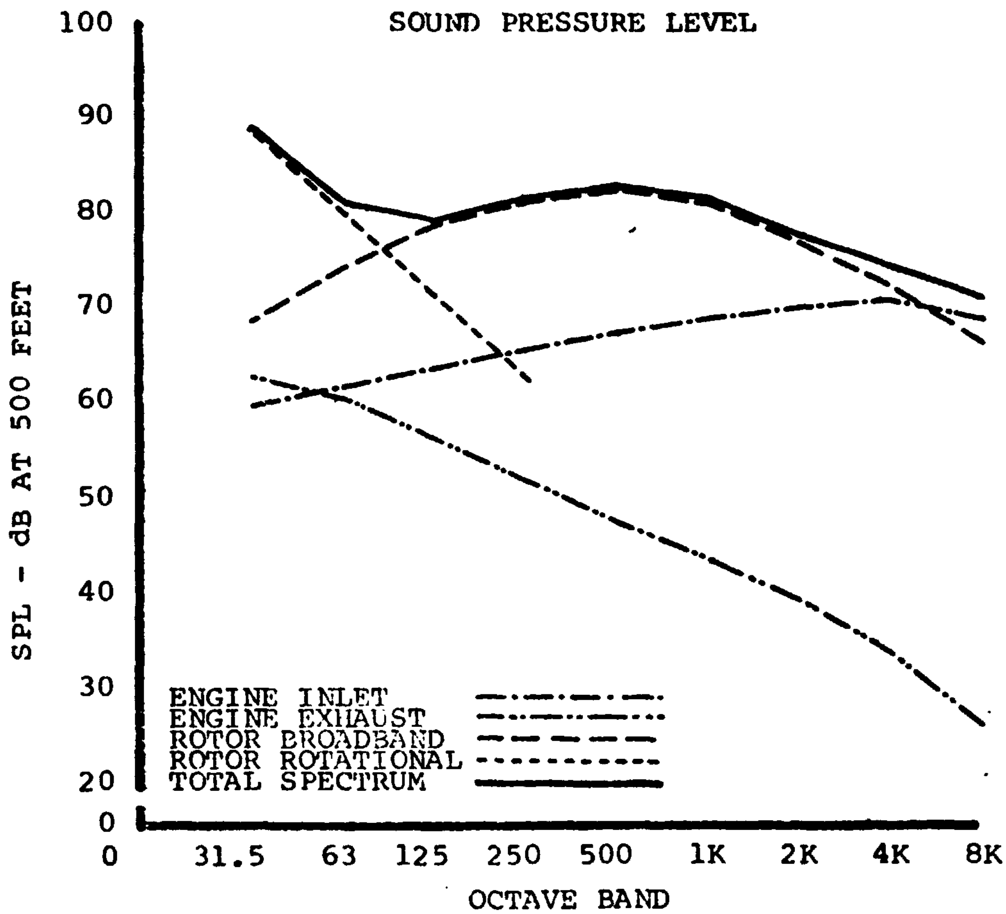
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 700, SIGMA = .138, CASE = 19, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 89.5

Figure 2.9p. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



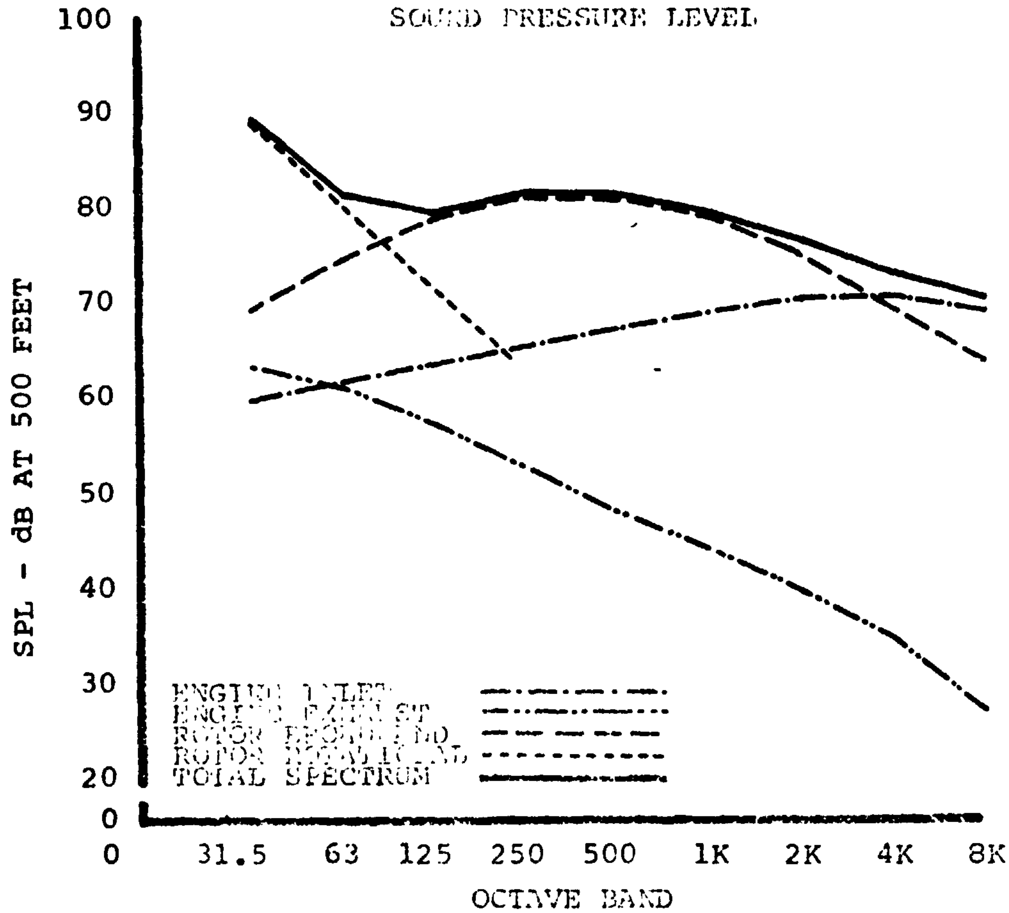
HELICOPTER HOVER NOISE SPECTRUC AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 700, S IGMA = .158, CASE = 20, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 88.7

Figure 2.9q. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



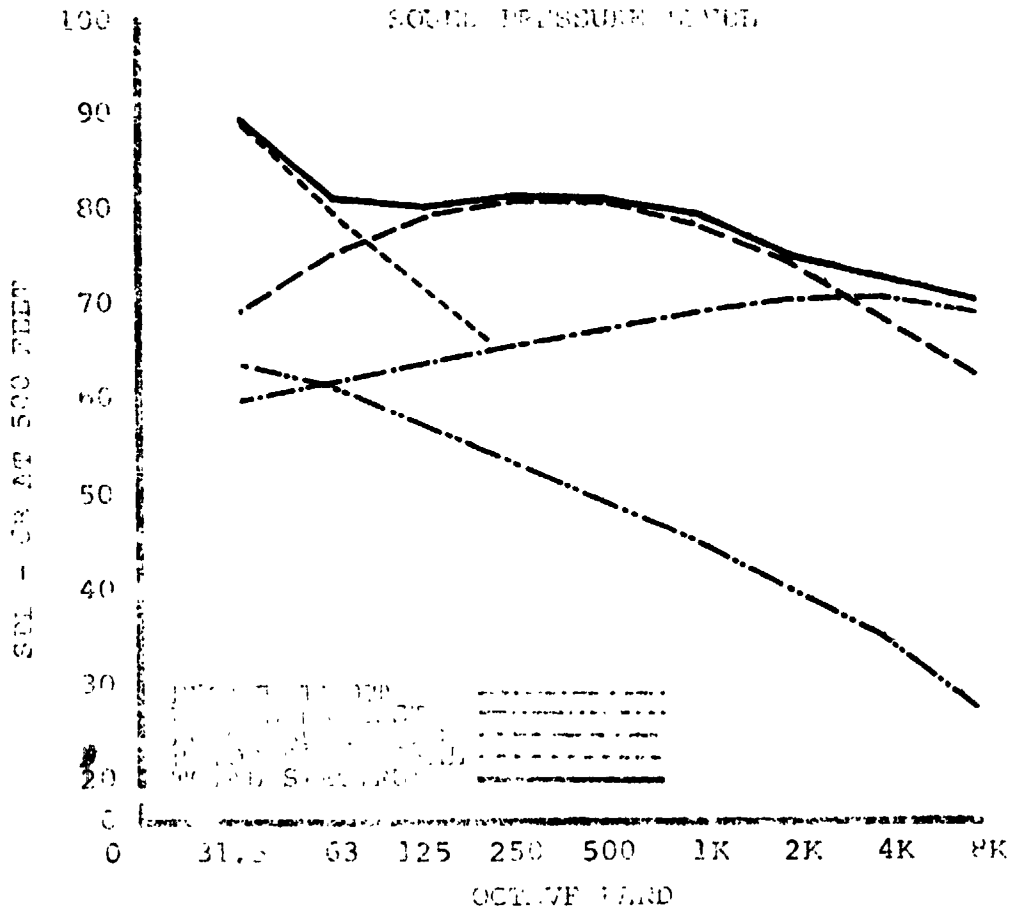
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 800, SIGMA = .062, CASE = 7, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 98.7

Figure 2.9r. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



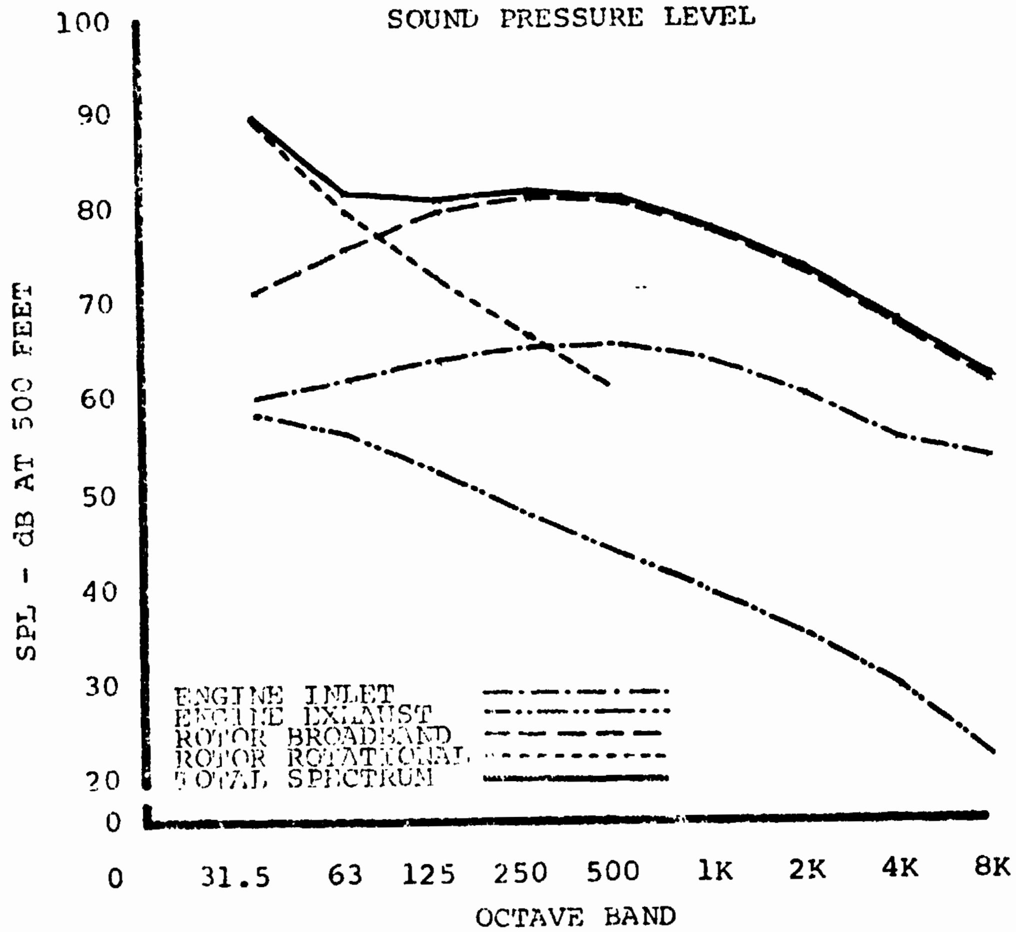
HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 800, SIGMA = .075, CASE = 5, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 97.7

Figure 2.9s. **Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.**



HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGER, VT = 800, SIGMA = .083, CASE = 6, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 97.3

Figure 2.9t. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 800, SIGMA = .093, CASE = 21, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 94.9

Figure 2.9u. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

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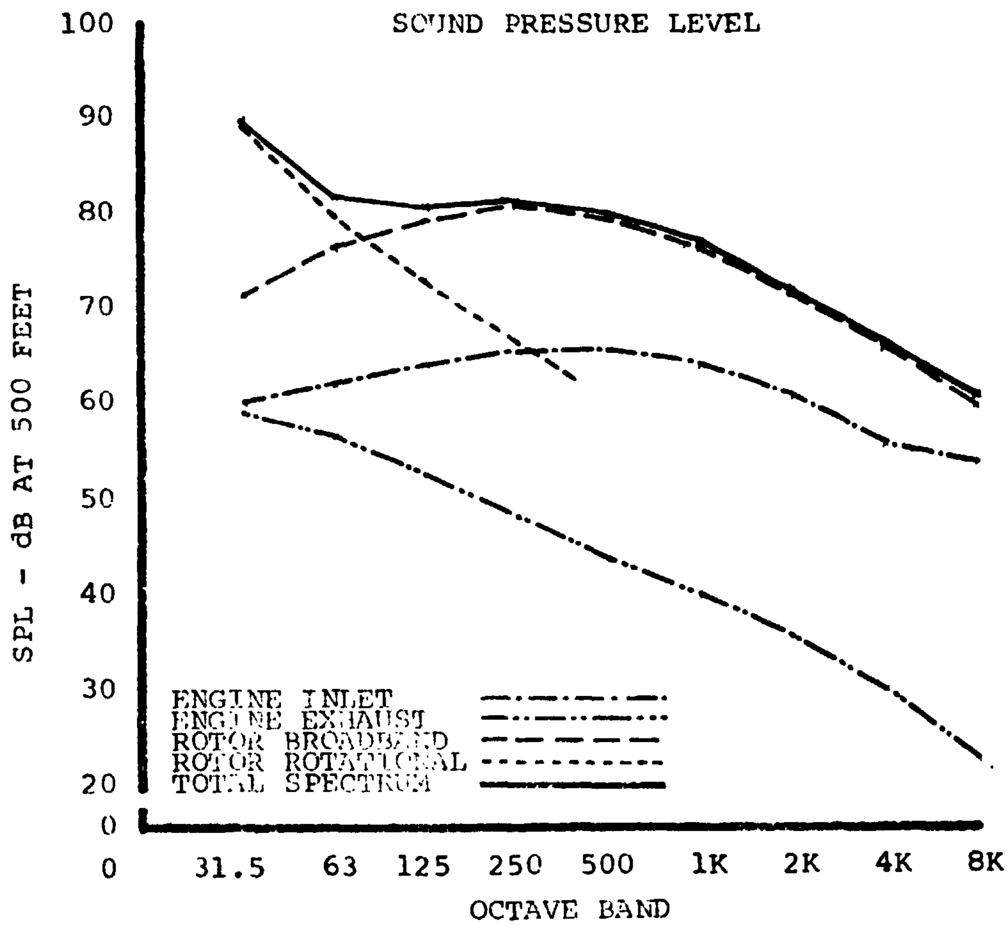
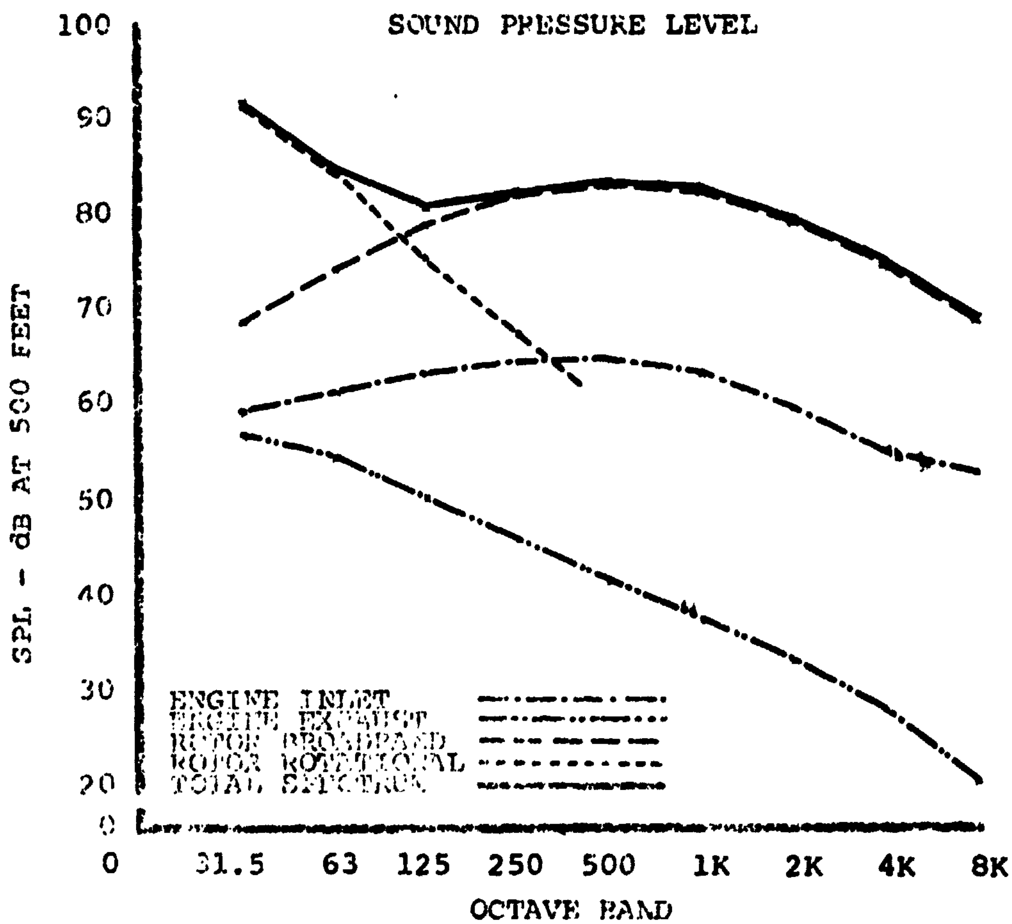


HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 800, SIGMA = .107, CASE = 22, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 93.9

Figure 2.9v. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 850, SIGMA = .059, CASE = 25, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 100.0

Figure 2.9w. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

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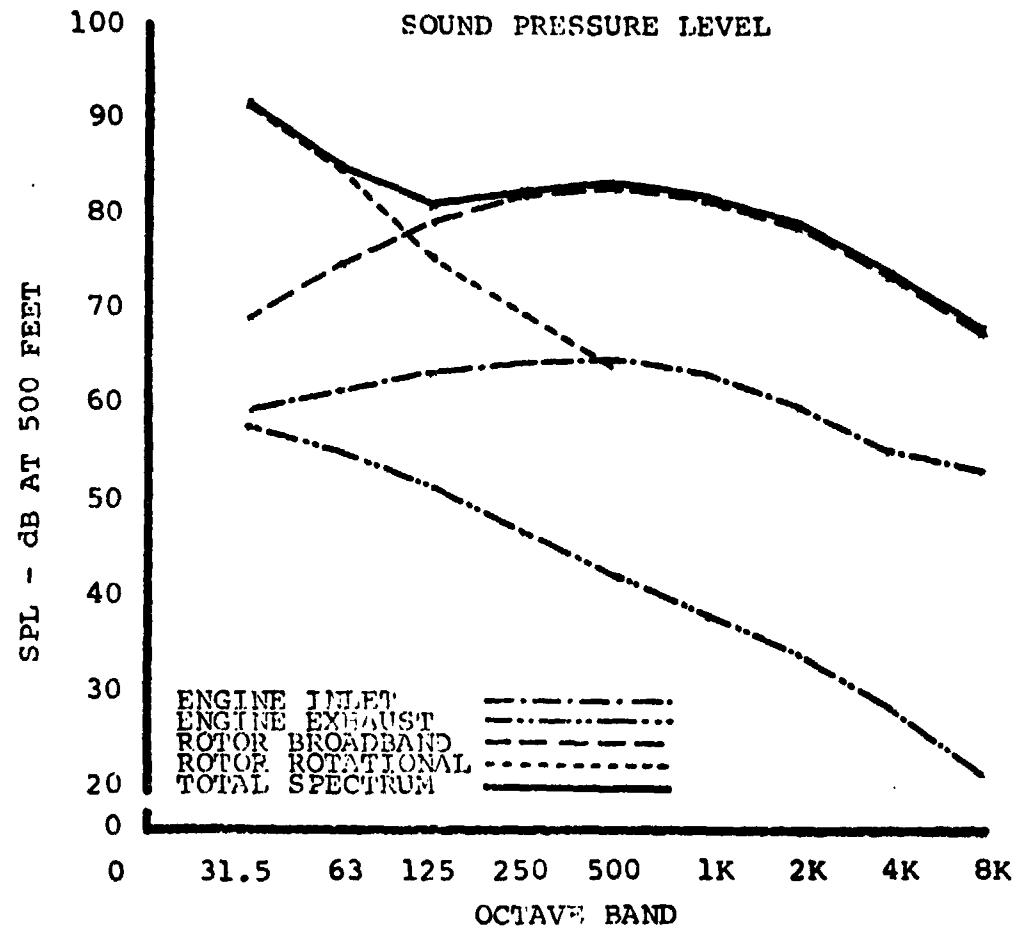
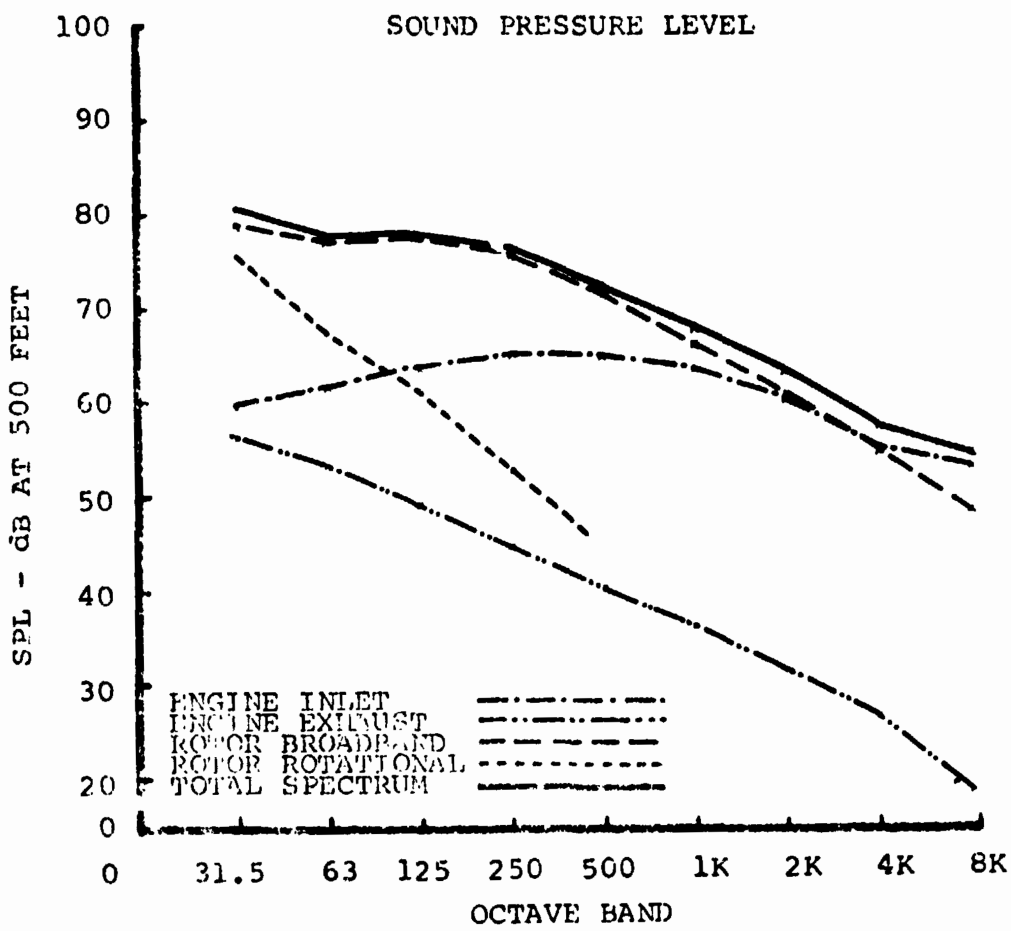


HELICOPTER HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 850, SIGMA = .065, CASE = 24, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 99.3

Figure 2.9x. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.



HELICOPTER D.P., -5 PNdB, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 640, SIGMA .159, PNdB = 86.9 WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER

Figure 2.9y. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

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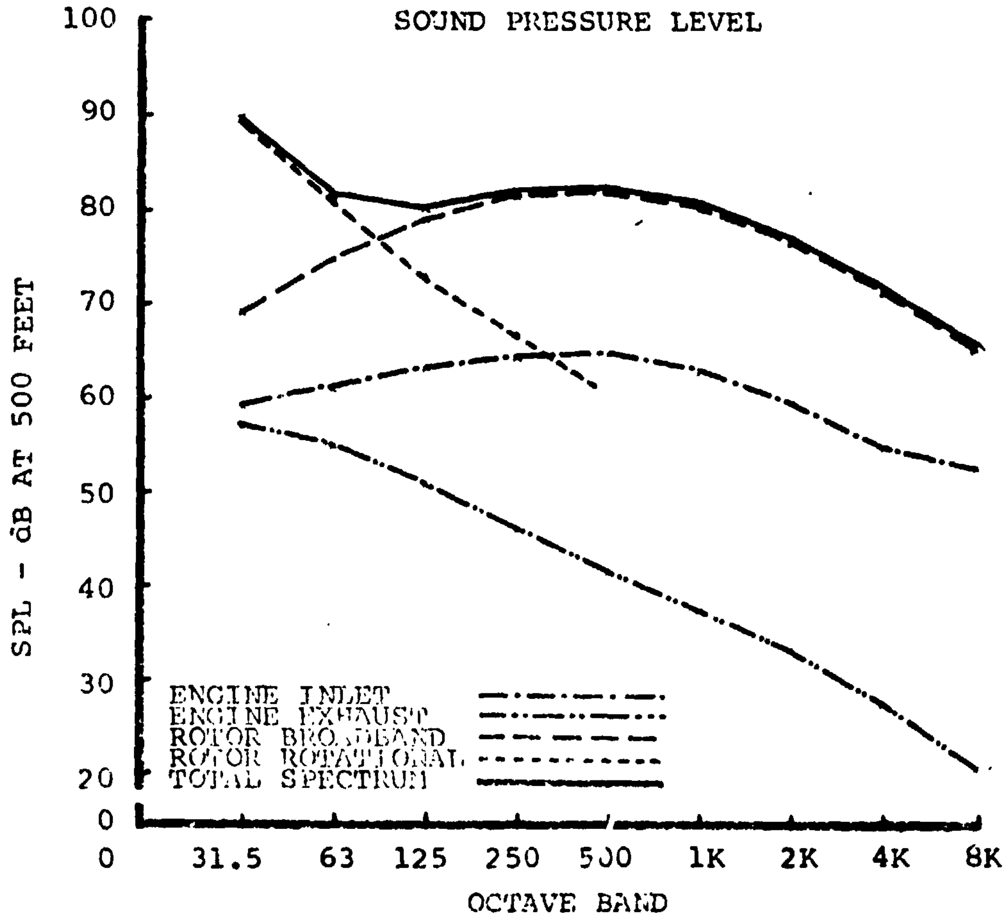

HELICOPTER D.P., -5 PNdB, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 810, SIGMA = .07, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 97.4

Figure 2.9z. Tandem Helicopter - Noise Derivative Trade Study. 100 Passengers. Altitude = 5,000 Feet. Disc Loading = 9 PSF.

2.3 TILT ROTOR AIRCRAFT - SIZING TREND DATA

The sizing procedure for the tilt rotor aircraft was done in much the same manner as for the tandem helicopters. The sizing trend data presented in this section is shown in the chronological order in which the data were generated. This is important to note since the weights, constants, drag, rotor performance, etc. which play a large role in defining the vehicle weight and performance are continuously checked and updated as more detailed data becomes available. Thus, the weights and performance of any specific parametric aircraft become more precise as the study progresses. The weight and performance levels of early trend data may thus be inconsistent, however, the data serves to indicate parametric sensitivities and allow design decisions to be made. For the tilt rotor the initial selection of aircraft characteristics were as follows:

100 passengers (seven abreast seating)
4 engines
Wing chord/prop diameter = .2
Cruise tipspeed = 0.7 hover tipspeed

The fuselage size was known from preliminary drawings and cabin layout data.

The effect of hover tipspeed and disc loading were first computed and led to the parametric data shown in Figures 2.10a to 2.10c.

In retrospect these parametric aircraft are overweight, however,

the trends indicate that increasing disc loading and tipspeed reduces the overall aircraft weight. These data were computed with the aircraft cruise altitude of 5,000 feet (i.e., cruise speed limit 250 knots EAS). Similar data using the same assumptions with a cruise altitude of 10,000 feet is shown in Figures 2.11a to 2.11c and at 15,000 feet in Figures 2.12 to 2.12c.

For altitudes of 5,000 and 10,000 feet the aircraft were constrained to cruise at 250 knots EAS. At 15,000 feet the cruise speed was limited by normal rated power available. The effect of design cruise altitude on gross weight is small. All three sets of parametric aircraft indicate that gross weight reduces as tipspeed and disc loading increase. The cruise speeds at 15,000 feet were not constrained by the 250 knot EAS limit and reflect the impact of disc loading as shown in Figure 2.12c. The normal rated power cruise speed increases as disc loading increases as a result of reduced aircraft size, drag and improved rotor efficiency.

A further set of parametric vehicles were sized at 10,000 feet altitude with the cruise speed defined by best range speed. This trade study was done to determine if significant aircraft weight could be saved by operating at maximum fuel efficiency. Comparison of the trend data, Figures 2.13a to 2.13c with the previous data, Figures 2.11a to 2.11c show only minimal savings in gross weight. This result is largely due to the intrinsic fuel efficiency of the tilt rotor configuration and the resulting low fuel fraction for the aircraft.

A disc loading of 12.5 pounds per square foot and a tipspeed of 750 feet per second were selected to be used to define the optimum altitude for cruise. Figures 2.14 a and 2.14b show the results of this study. Figure 2.14a shows that design gross weight, mission fuel and weight empty all decrease as design cruise altitude increases. A discontinuity occurs at 10,000 feet where the vehicle is no longer constrained to the 250 knot EAS cruise speed limit.

The effect of altitude on cruise speed and direct operating cost is shown in Figure 2.14b.

Below 10,000 feet the 250 knot EAS restriction defines the cruise speed. At 10,000 feet there is a discontinuity up to the cruise speed defined by the transmission torque limit (sized in hover). The intersection of transmission torque limit and the NRP power limit occurs at 13,000 feet and results in power limited aircraft above this altitude.

These variations of weight and speed define the impact o design altitude on direct operating cost shown in Figure 2.14b. The minimum cost aircraft defines the optimum cruise altitude at 14,000 feet. This altitude was selected for all the subsequent trend studies.

With the altitude selected at 14,000 feet the basic input data to the trend studies in the areas of rotor performance and cabin pressurization and weights data were revised.

The effect of number of passengers on aircraft size, economics and noise levels is shown in Figures 2.15a to 2.15n for

various disc loadings. For these trades, hover tipspeed was held constant at 750 feet per second.

The impact of number of passengers on gross weight is shown in Figure 2.15a. The design gross weight almost doubles as the number of passengers is increased from 50 to 100. For the same number of passengers rotor diameter increases approximately 50% and power by 100% as shown in Figure 2.15b. The fuel efficiency of the air aft improves as number of passengers increases as shown in Figure 2.15c.

The effect of size (i.e., number of passengers) on 500-foot sideline perceived noise is minimal as shown in Figure 2.15d. The 50 passenger aircraft are a maximum of 2 PNdB lower than the 100 pass enger aircraft.

Figure 2.15c shows the impact of aircraft size on operating economics and indicates a large reduction in direct operating costs as number of passengers increases. Economics are the largest governing factor in successful short haul commercial operation and therefore a 100 passenger aircraft was selected.

Hover noise spectrum data in terms of sound pressure level and NOY values as a function of octave band frequency are shown for each point of the sizing matrix in Figure 2.15f through 2.15n.

All of the trend studies up this point have assumed that the cruise RPM is 70% of hover RPM. The effect of varying this ratio was checked and the data is shown in Figures 2.16a to 2.16c.

Reducing the cruise RPM reduces the design gross weight and the curves indicate that the minimum weight is almost achieved at 0.7 (Figure 2.16a).

The installed power is a minimum at V_{TC}/V_{TH} = 0.7 although the fuel weight reduction indicates further gains could be made as shown in Figure 2.16b.

A major result of cruise RPM reduction is the increase in normal rated power cruise speed as shown in Figure 2.16d.

Although some small advantage in weight, cruise speed and fuel weight is apparent in these charts at tipspeed reductions lower than 0.7. This value was held in order to simplify subsystem design. For example, current electrical generators can handle a thirty percent variation in drive RPM, however, to go further requires compensating devices to maintain output frequencies. Subsystem complexity of this nature would incur a small weight penalty which would offset the apparent advantage at greater tipspeed reductions.

The trend data for tipspeed and disc loading were reworked at the selected cruise altitude of 14,000 feet. These data are shown in Figures 2.17a to 2.170. The trends previously observed in the altitude trade studies are confirmed at the design altitude.

The direct operating costs for these aircraft are shown in Figure 2.17d and indicate that high tipspeed and high disc loading reduce costs.

Figure 2.17e summarizes the gross weight, direct operating cost and noise level data for these vehicles.

The disc loading was selected to be 15 pounds per square foot. The trend data indicate further reductions in direct operating cost at higher disc loadings. A disc loading of 15 pounds per square foot was considered a maximum from ground wash considerations and by examination of hover yaw control requirements.

The hover tipspeed was selected at 775 feet per second to maintain a 500-foot sideline noise level of less than 100 PNdB and also by rotor tip critical Mach number considerations.

The remaining major design parameters to be selected were wing loading and rotor blade loading. Figures 2.18a to 2.18e shows trend study data giving the impact of wing loading and hover design C_T/σ on the aircraft size and performance. Increasing wing loading decreases the aircraft gross weight and improves cruise speed and gust sensitivity in cruise. The design wing loading of 100 pounds per square foot was selected as being the maximum desirable since the minimum cruise configuration speed increases as wing loading increases. This effect is shown in Fgiure 2.18d. The flaps up operating speed was held at less than 200 knots by selecting a wing loading of 100 pounds per square foot and the resulting flaps down operating speed is 150 knots giving an end of conversion speed range of from 150 knots to 195 knots.

Increased blade loading (i.e., increased C_T/σ) also decreases aircraft weight and improves the cruise speed. An assessment of the maximum desirable C_T/σ was made on the basis of blade shank size. Assuming that hover rotor loads at maximum yaw control define the endurance limit loads, an estimate of the required blade shank diameter was made and the smallest solidity compatible with the shank size selected to ensure design feasibility. This limit is shown as a broken line on Figures 2.18a to 2.18c and at a wing loading of 100 pounds per square foot defines the design C_T/σ in hover to be 0.126.

This selected design parameter indicated a design gross weight of 75,030 pounds.

At this point a detailed rotor design, weights review, stability and control checks, and aircraft layout review were made and the resulting refined aircraft sized to give a design gross weight of 74,749 pounds as shown in Table ' 14, Volume I and in Section 3 of this document.

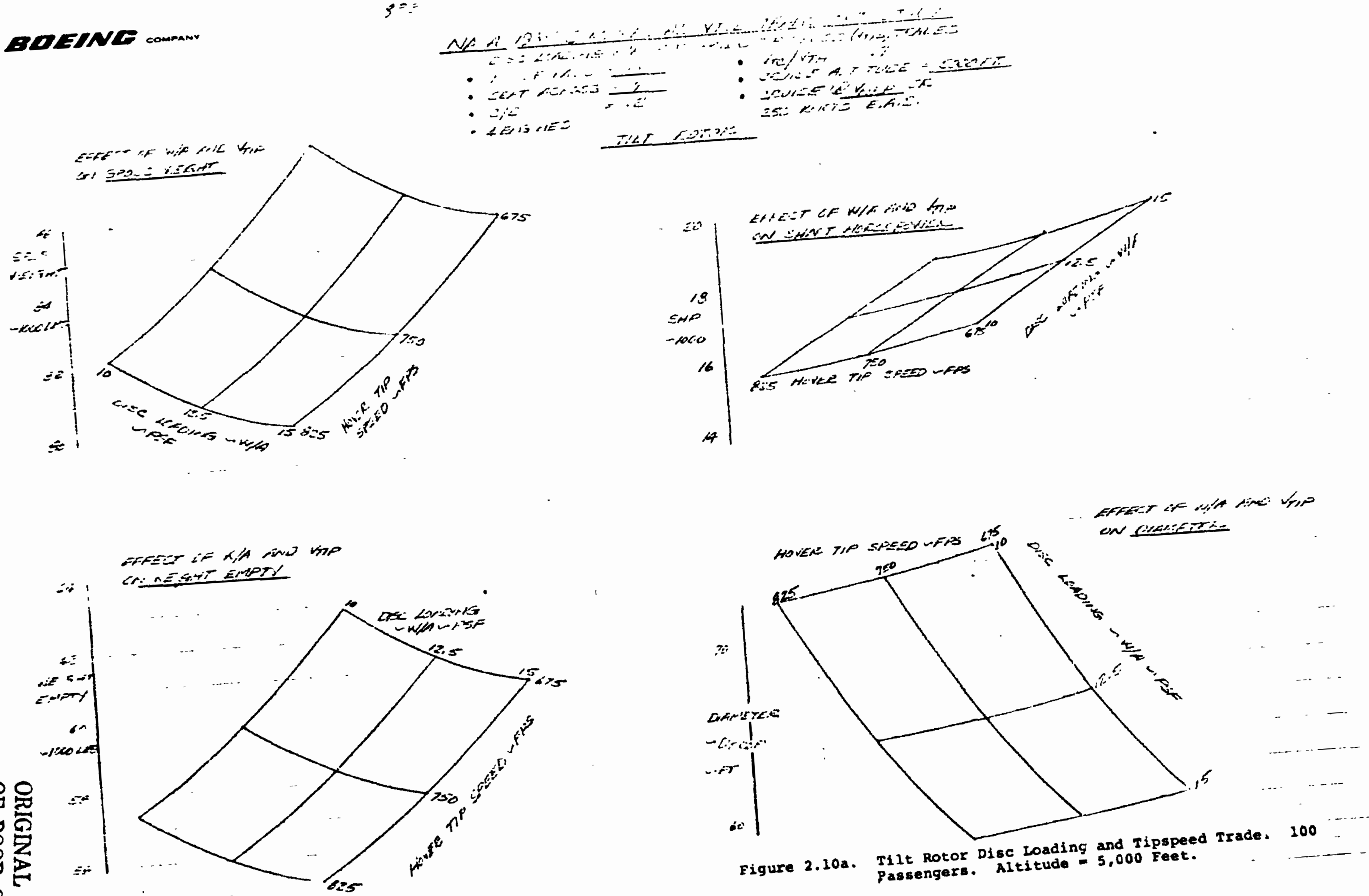

Figure 2.10a. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet.

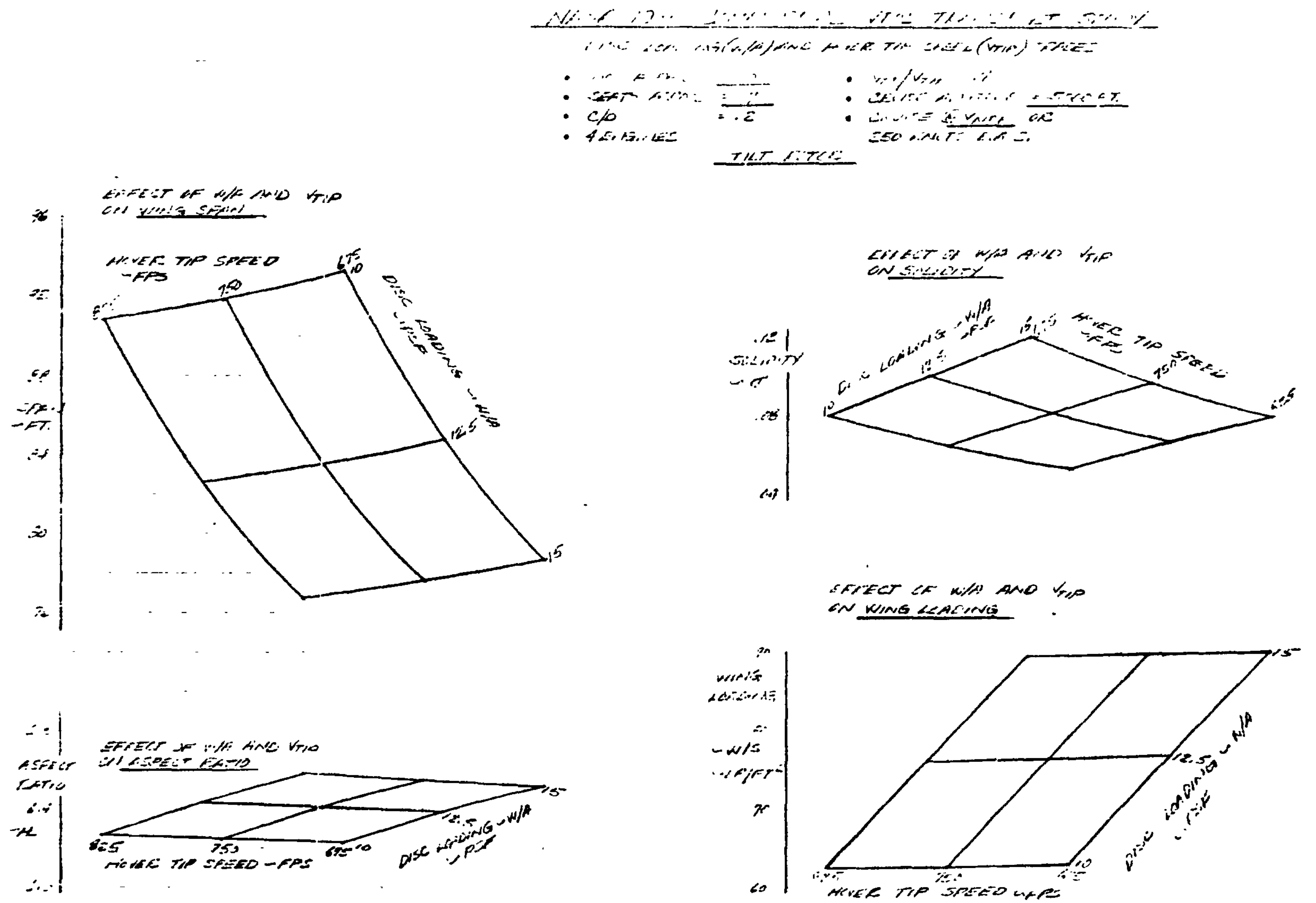

Figure 2.10b. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet.

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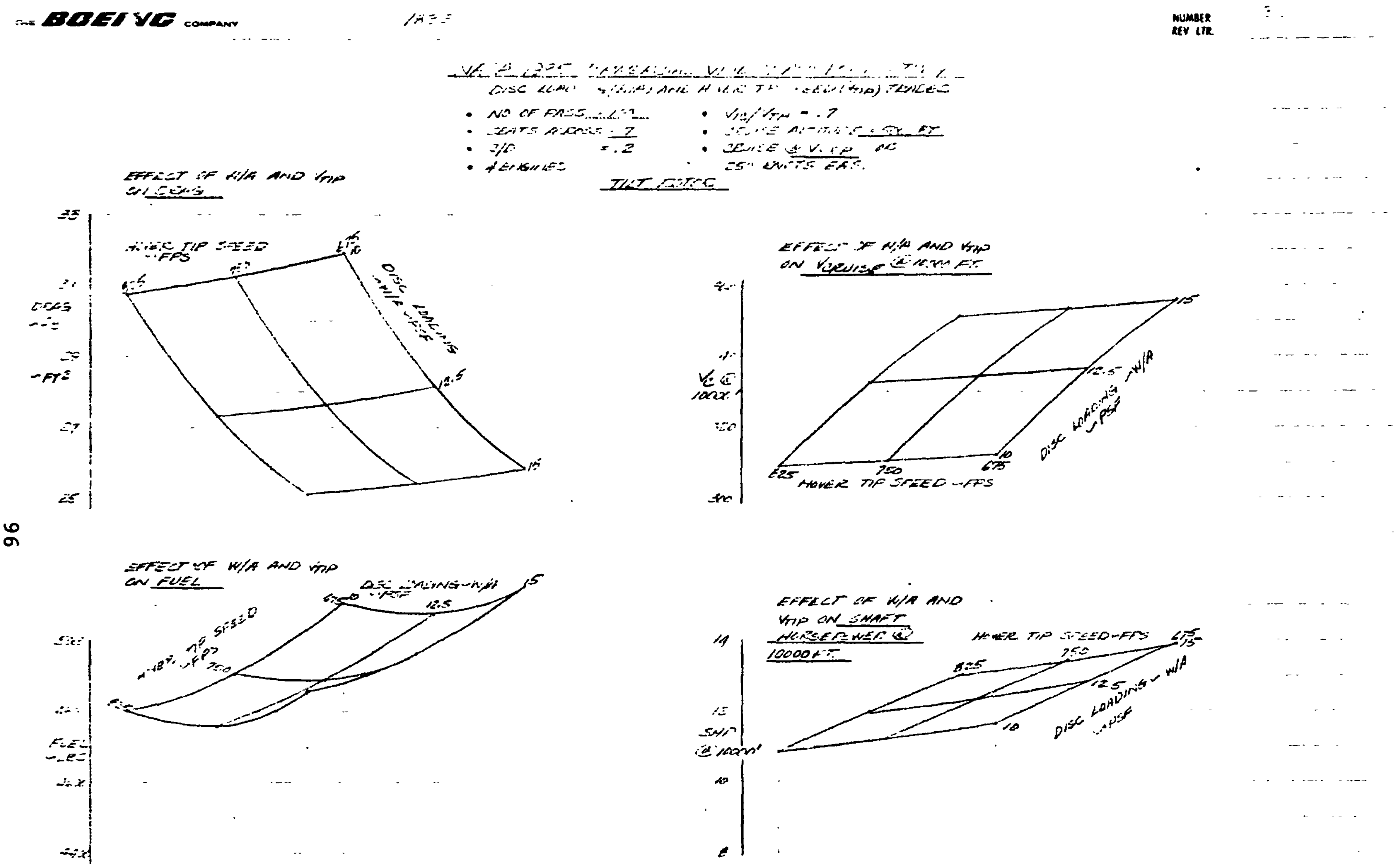

Figure 2.10c. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 5,000 Feet.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND HOVER TIP SPEED (V_{TIP}) TRADES

- NO OF PASS = 100
- SEATS ACROSS = 7
- C/D = 1.2
- 4 ENGINES
- V_{TR}/V_{TH} = .7
- CRUISE ALTITUDE = 10000 FT
- CRUISE AT V_{MCP} OR 350 KNOTS E.A.S.

TILT ROTOR

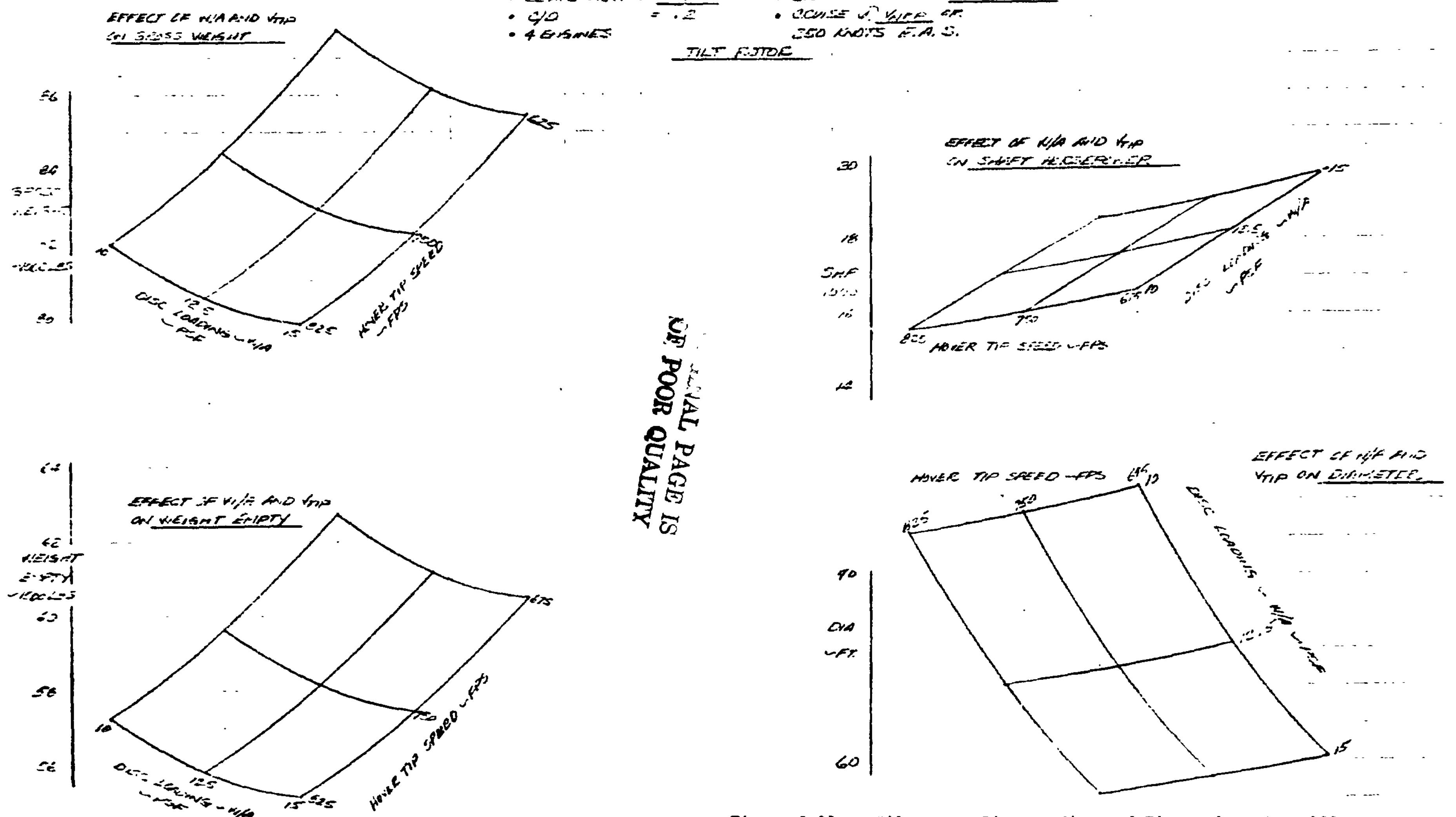

Figure 2.11a. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 10,000 Feet.

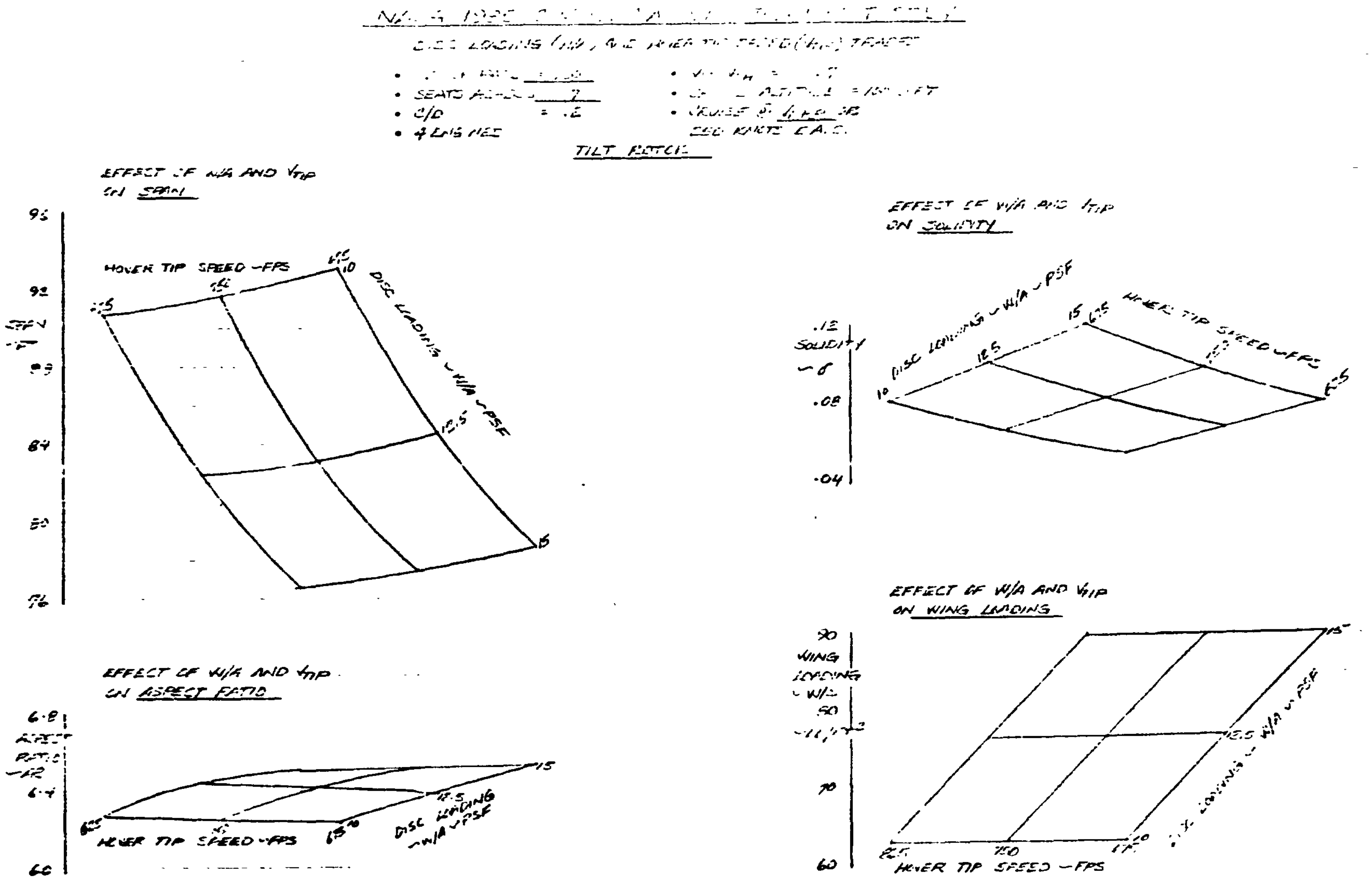

Figure 2.11b. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 10,000 Feet.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND HOVER TIP SPEED (V_{TIP}) TRADES

- NO OF PASS = 100
- SEATS ACROSS = 7
- C/D = .2
- 4 ENGINES
- V_{TO}/V_{TH} = .7
- CRUISE ALTITUDE = 10,000 FT.
- CRUISE @ V_{MCP} OR 350 KNOTS E A S.

TILT ROTOR

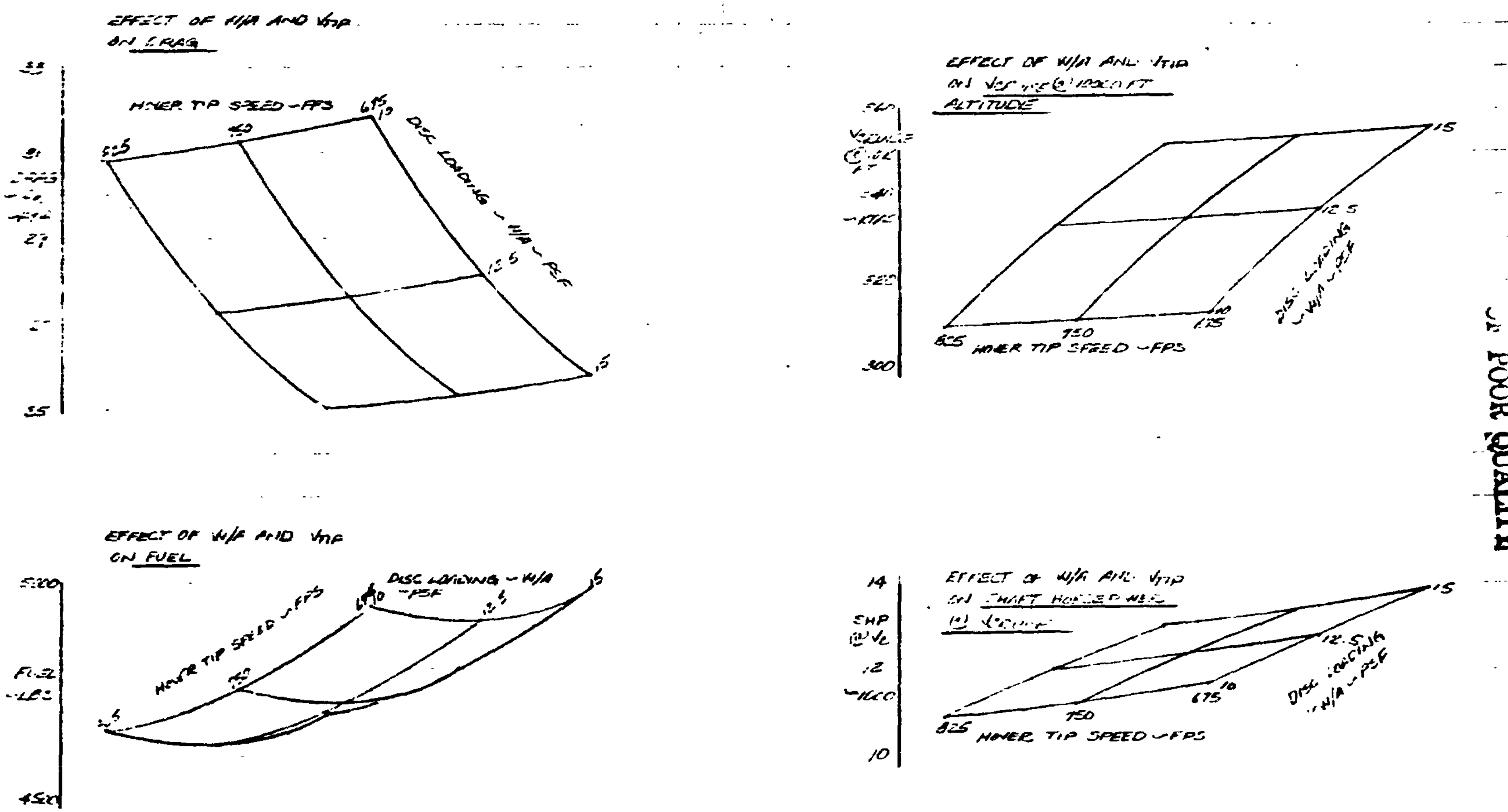

Figure 2.11c. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 10,000 Feet.

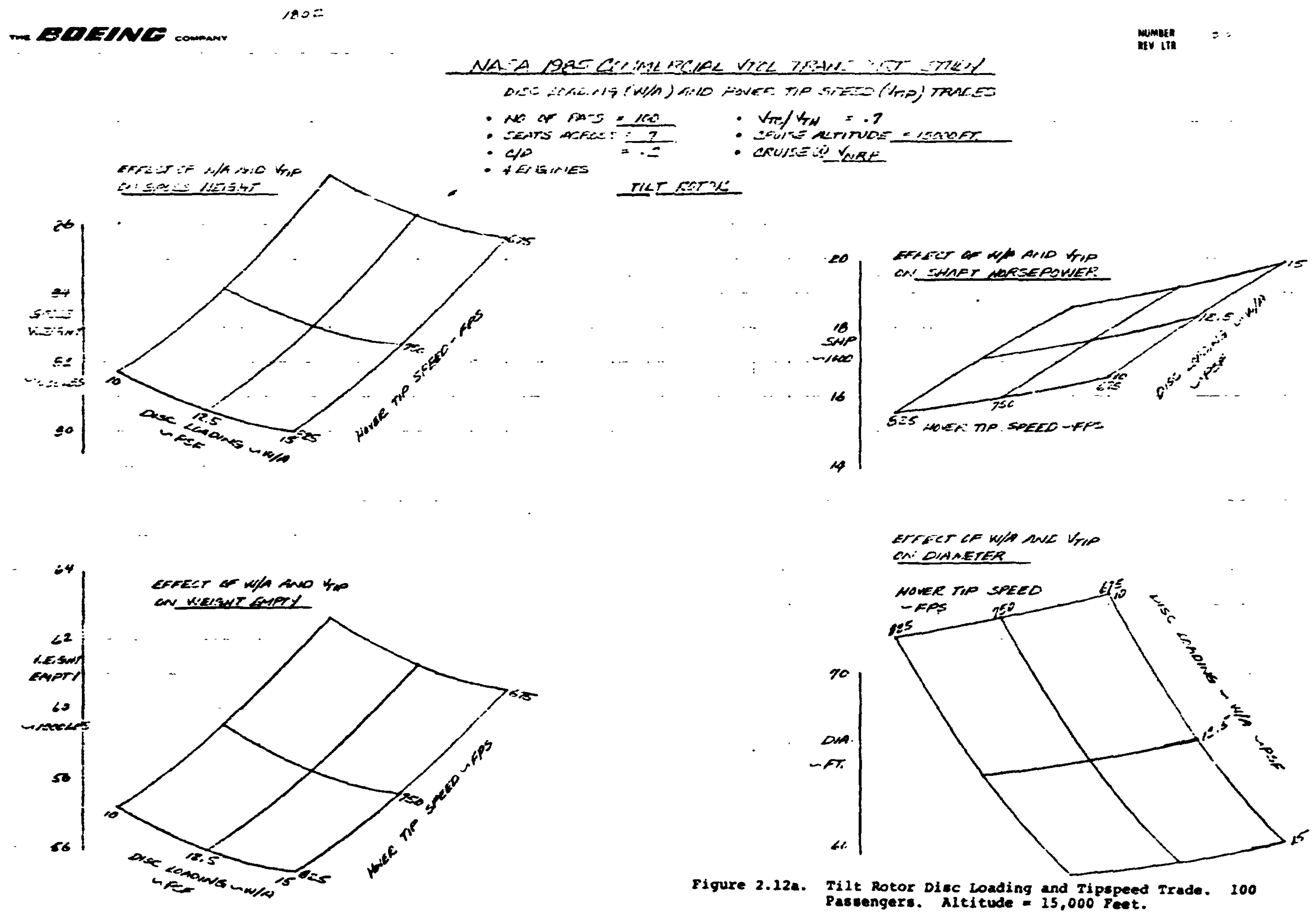

Figure 2.12a. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 15,000 Feet.

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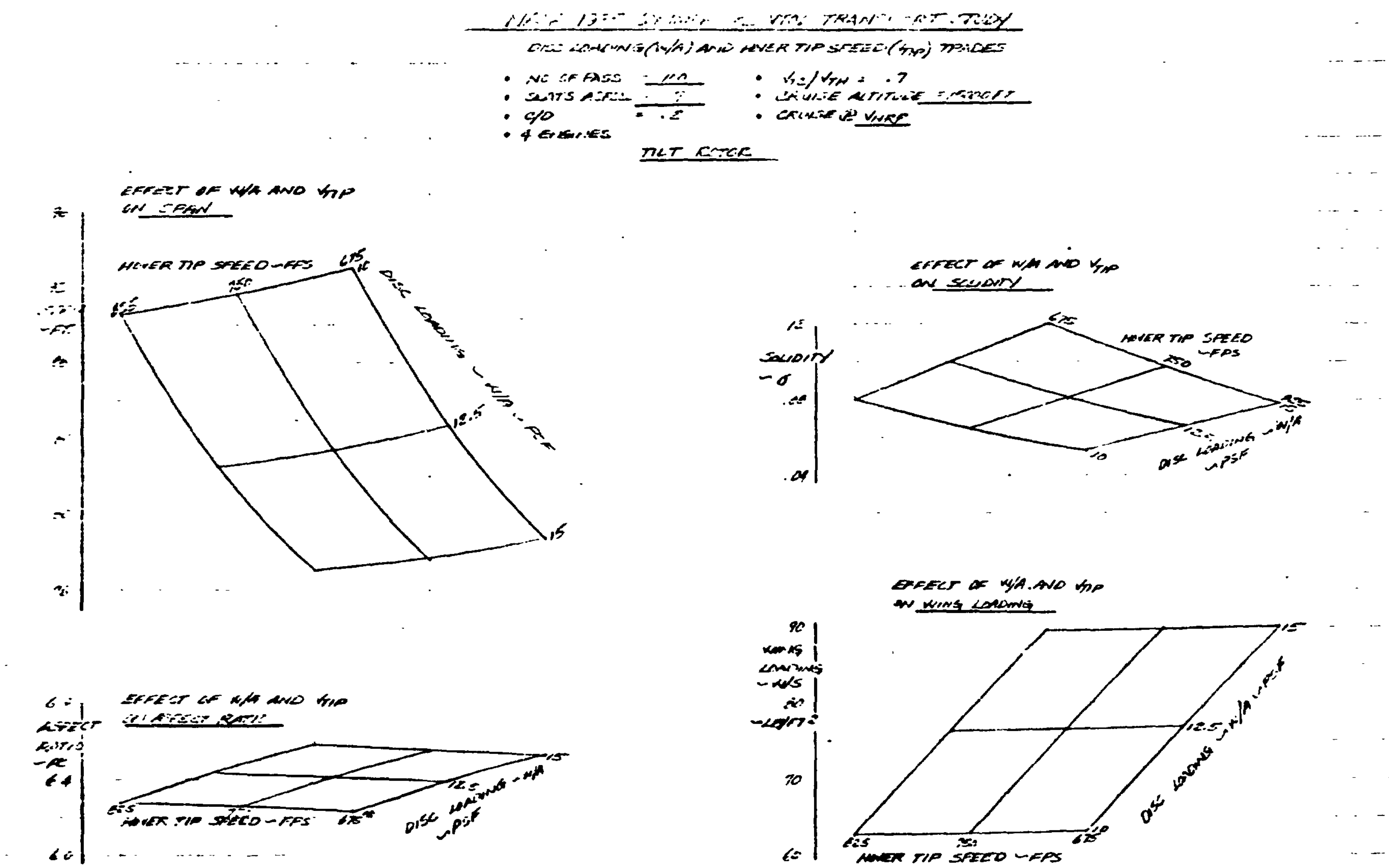

Figure 2.12b. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 15,000 Feet.

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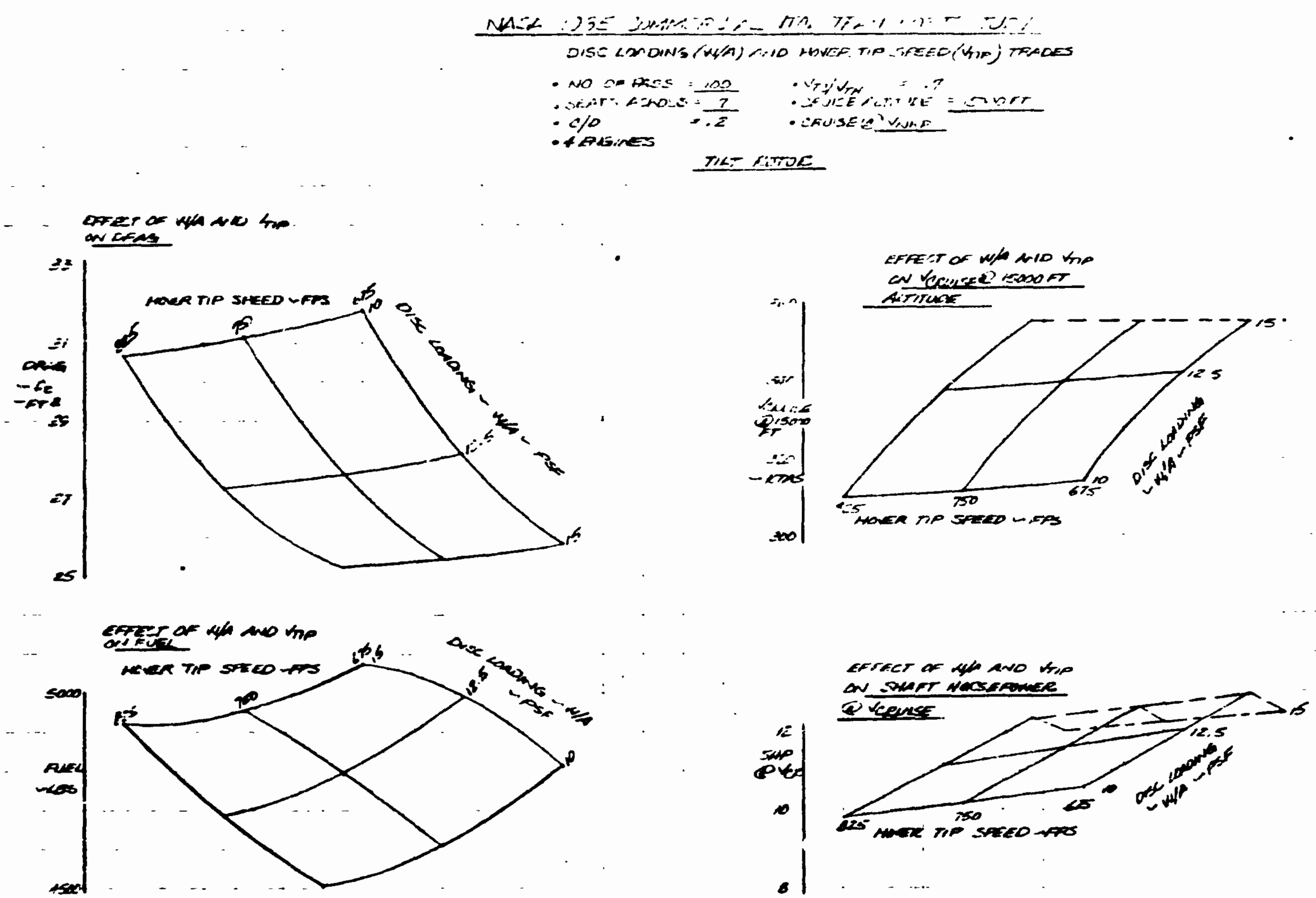

Figure 2.12c. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 15,000 Feet.

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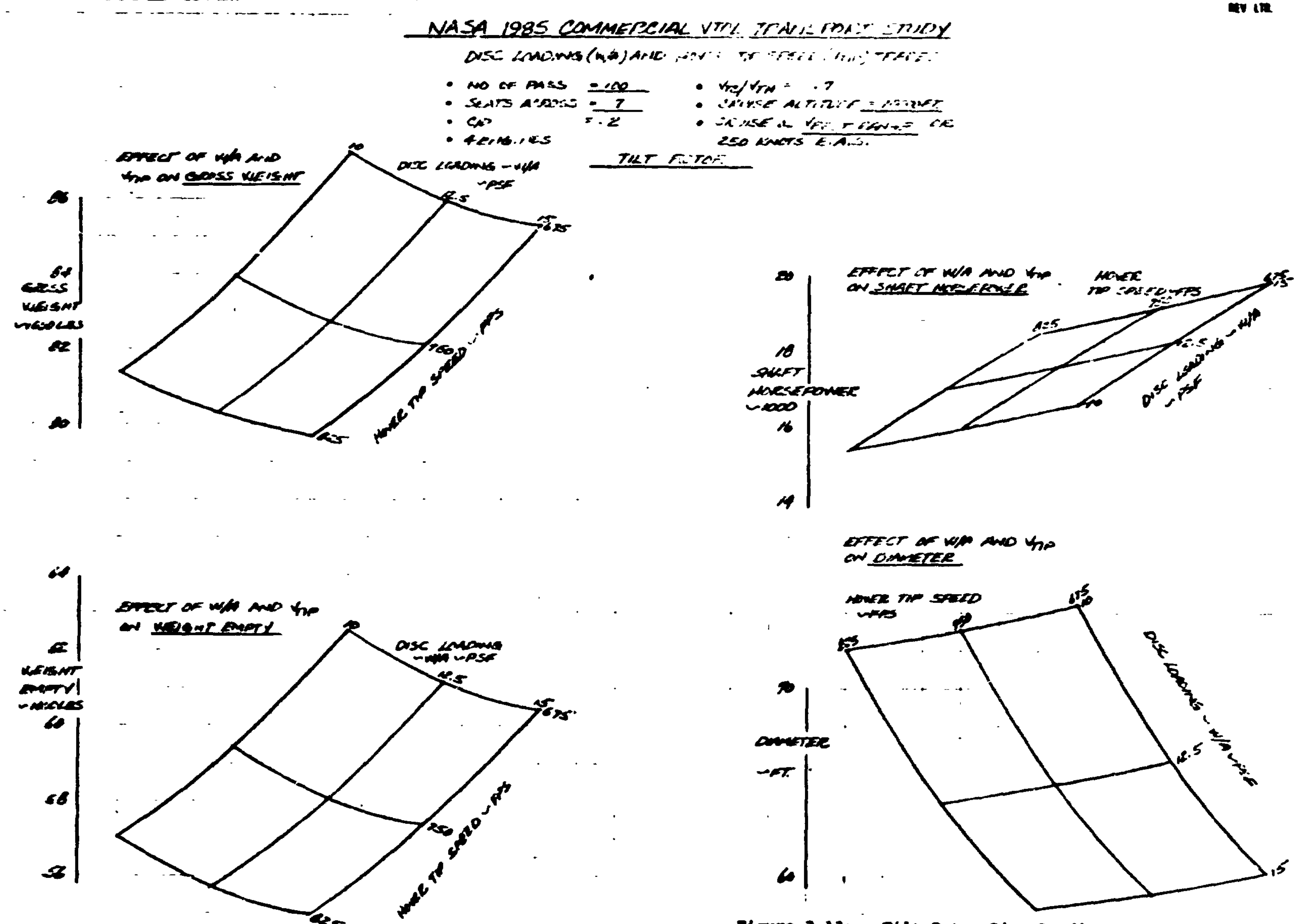

Figure 2.13a. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 10,000 Feet. Cruise at Best Range Speed.

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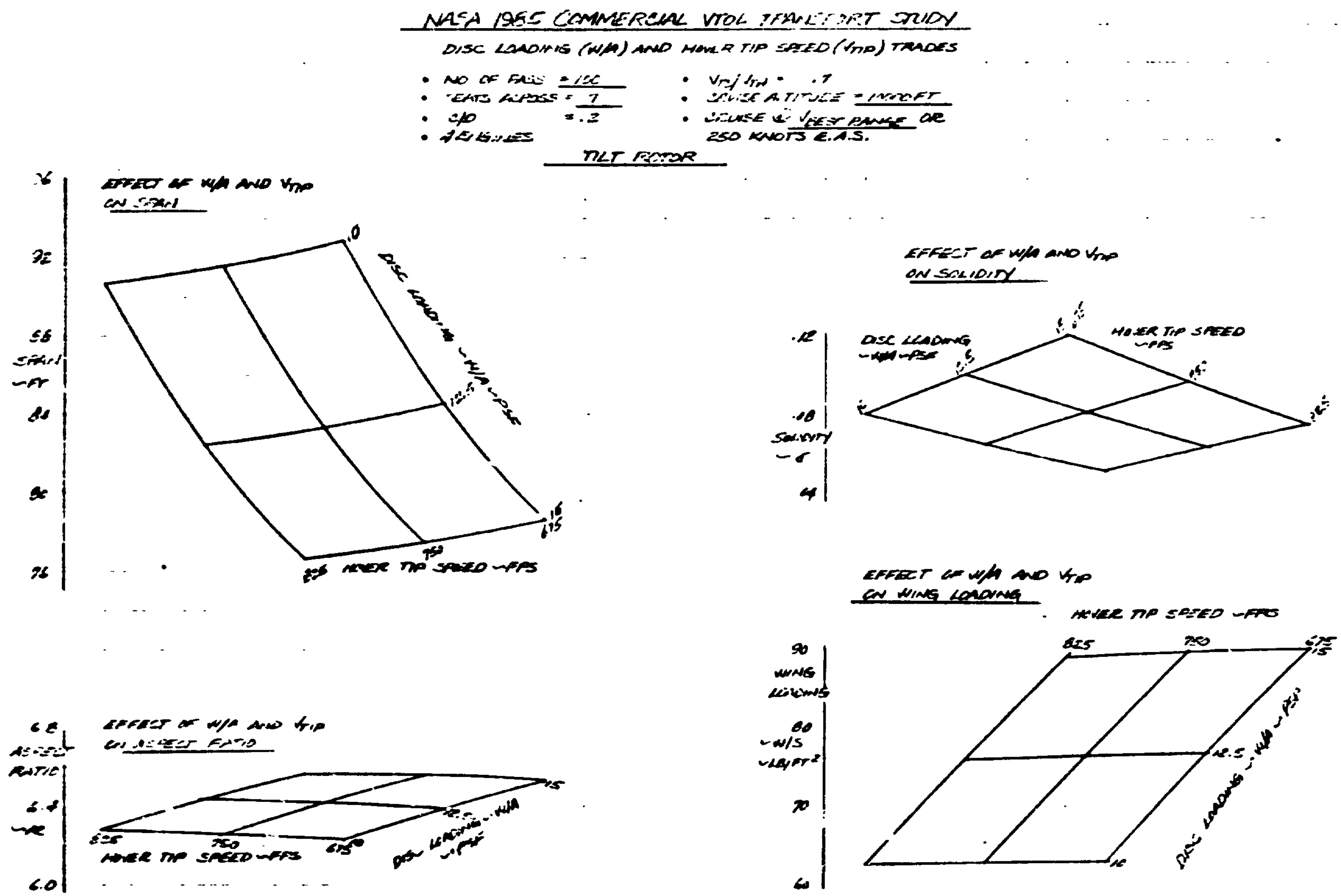

Figure 2.13b. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 10,000 Feet. Cruise at Best RAnge Speed.

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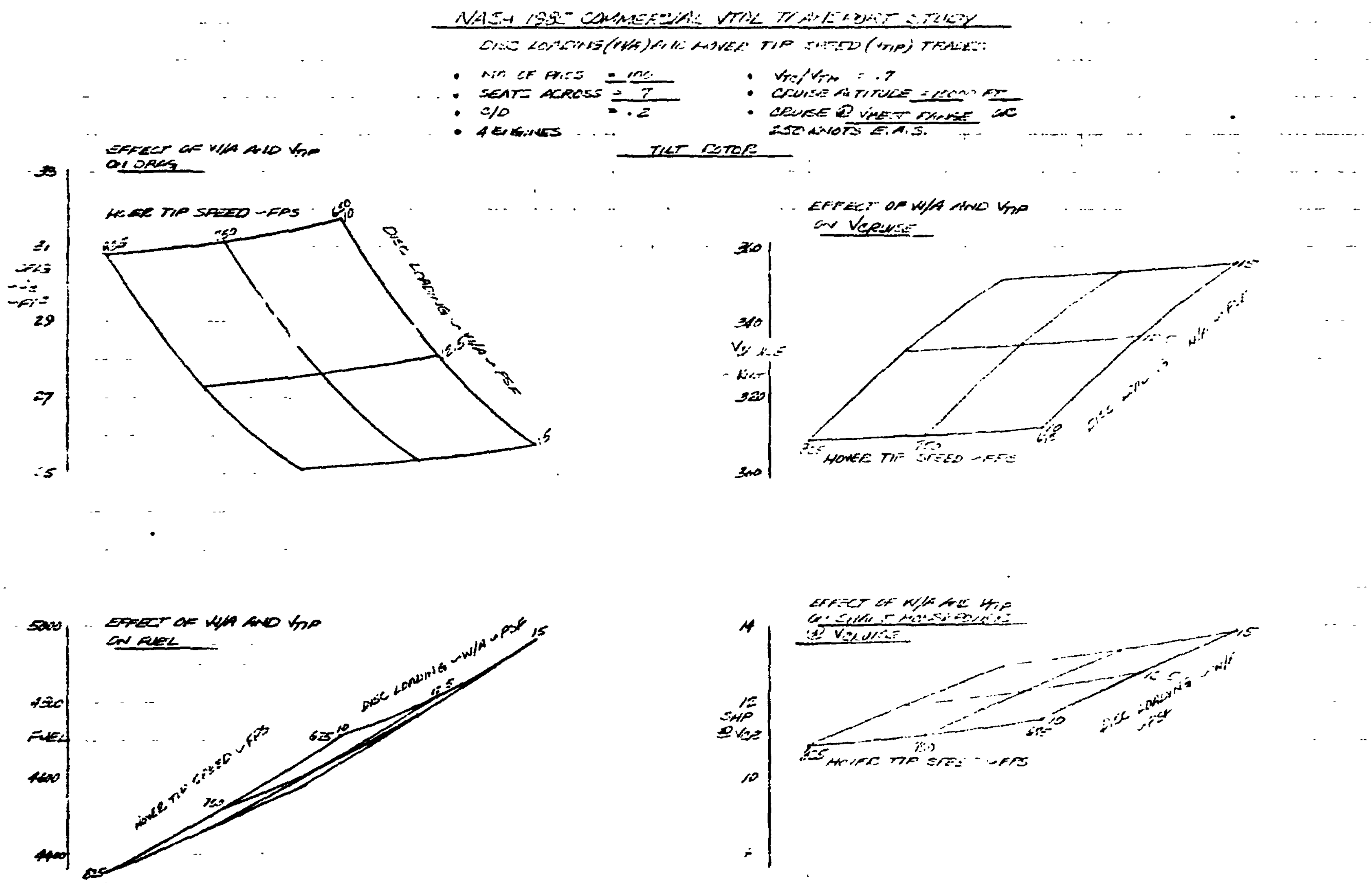

Figure 2.13c. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 10,000 Feet. Cruise at Best Range Speed.

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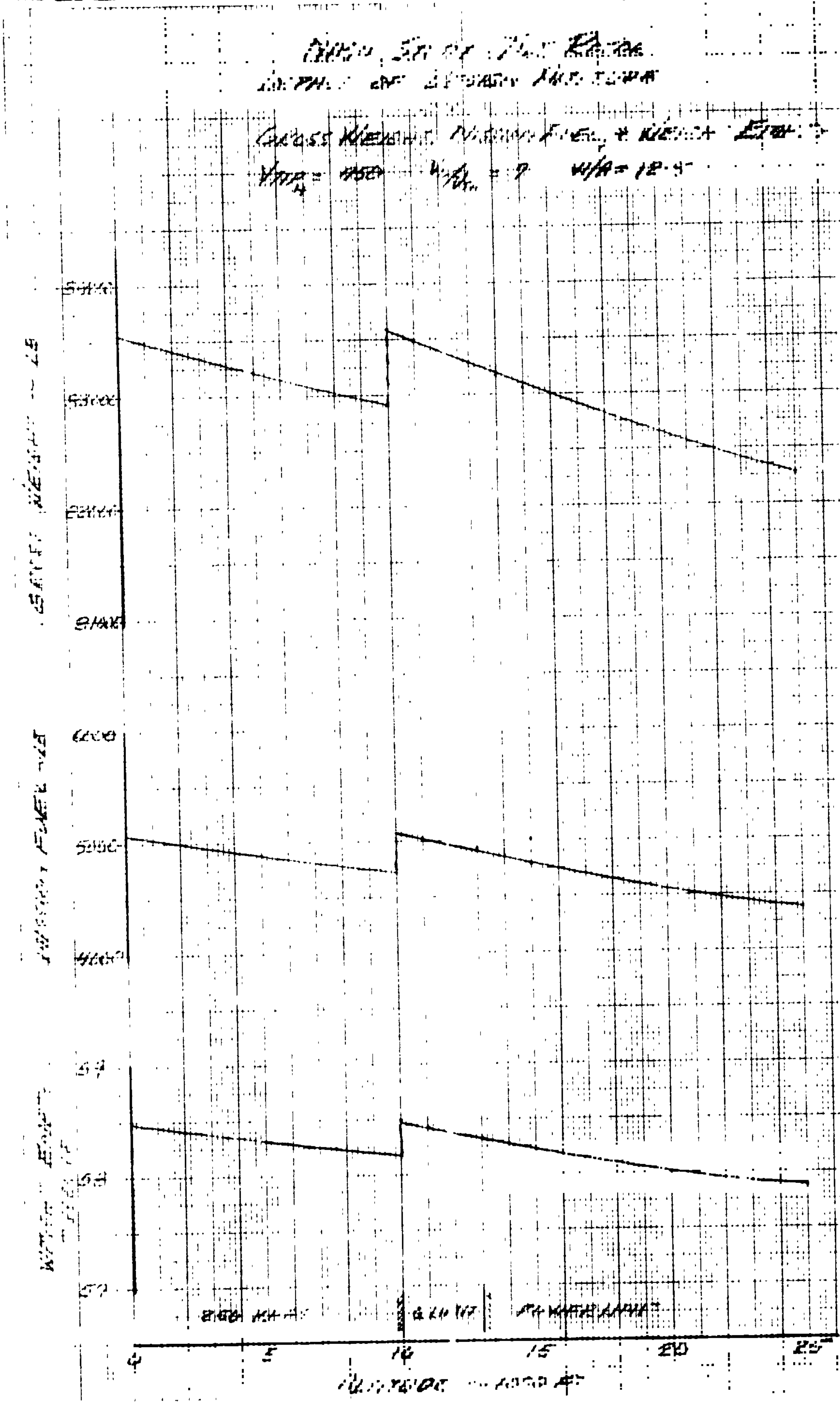

Figure 2.14a. Tilt Rotor Cruise Altitude Selection.

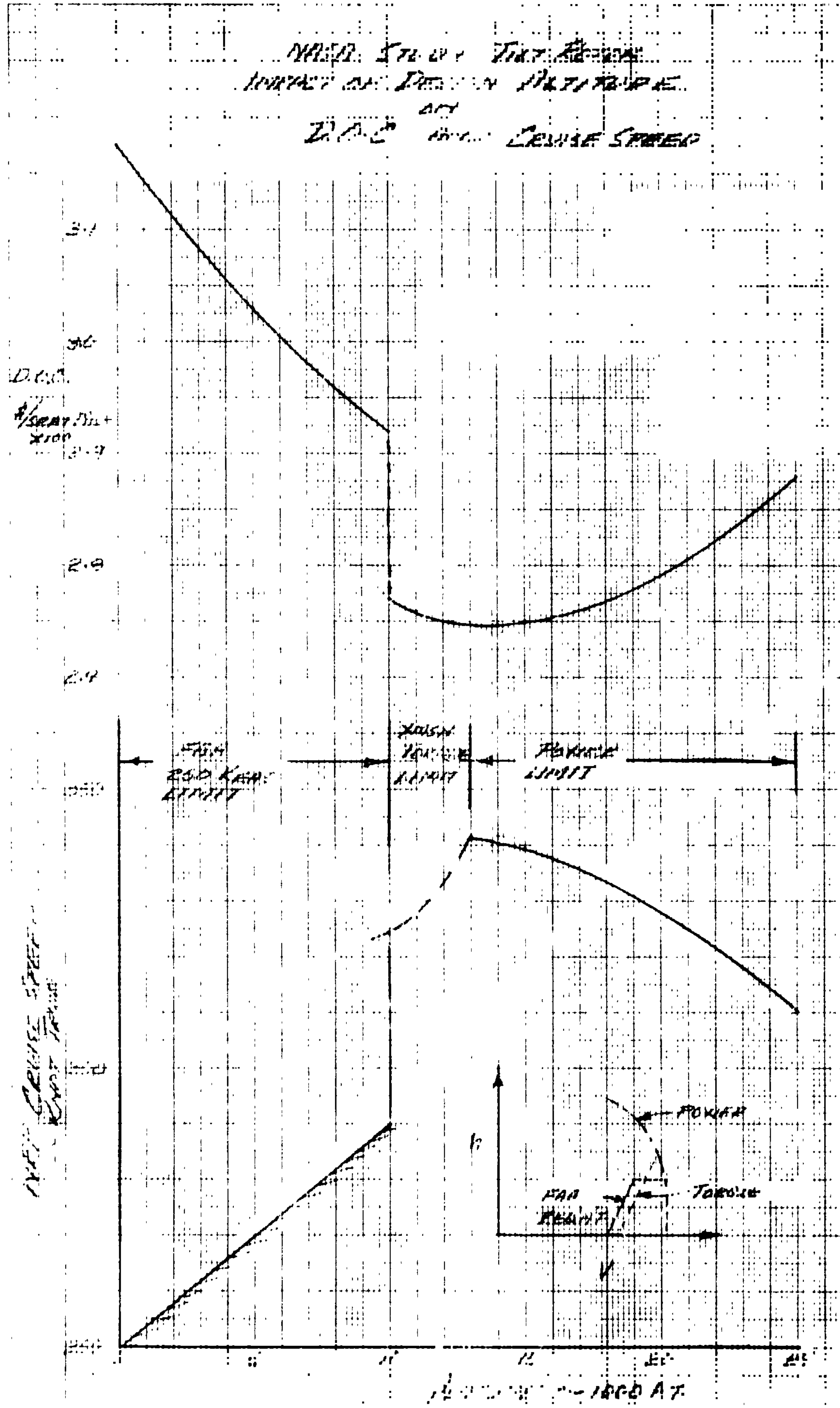

Figure 2.14b. Tilt Rotor Cruise Altitude Selection.

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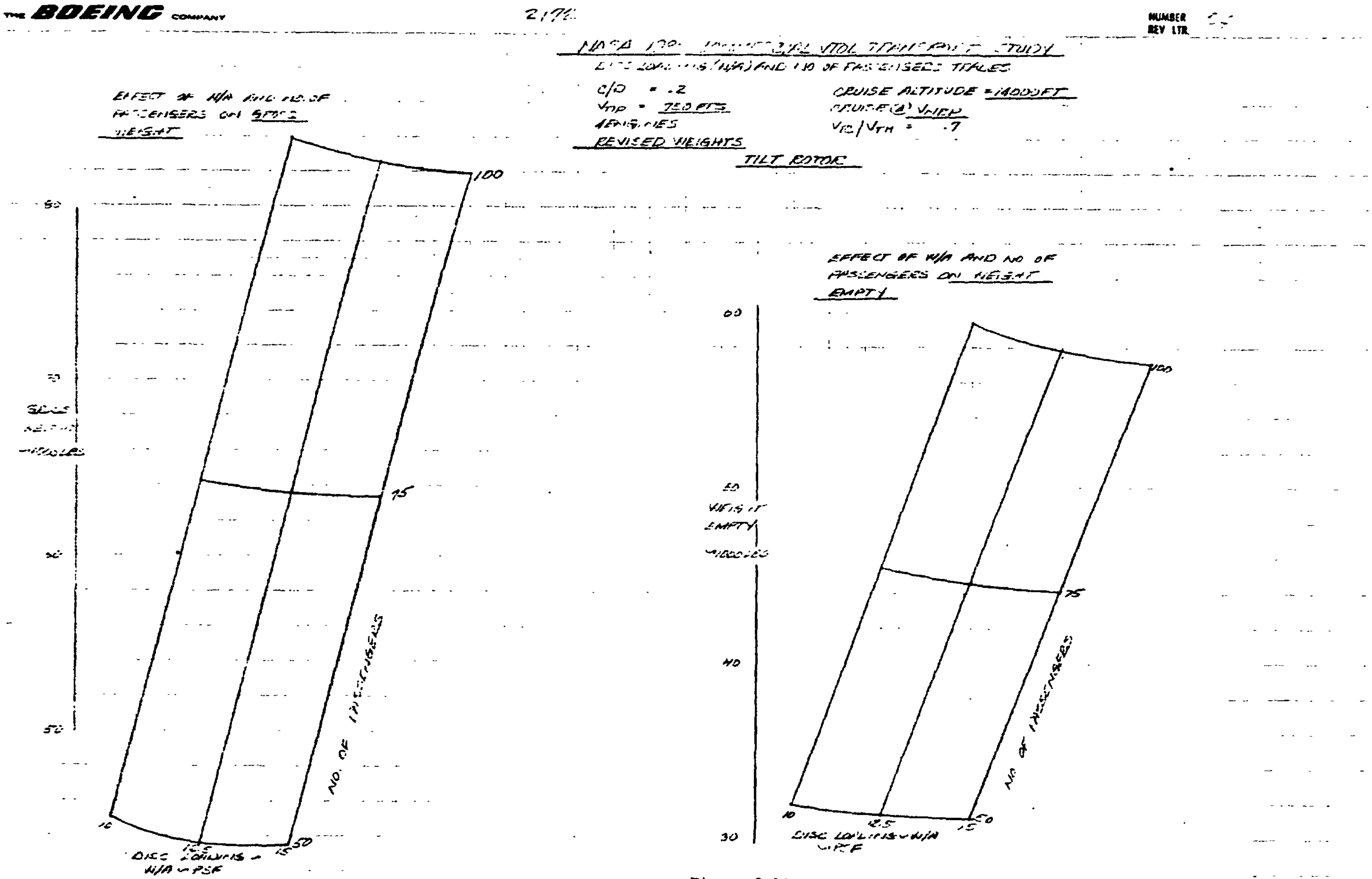

Figure 2.15a. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.

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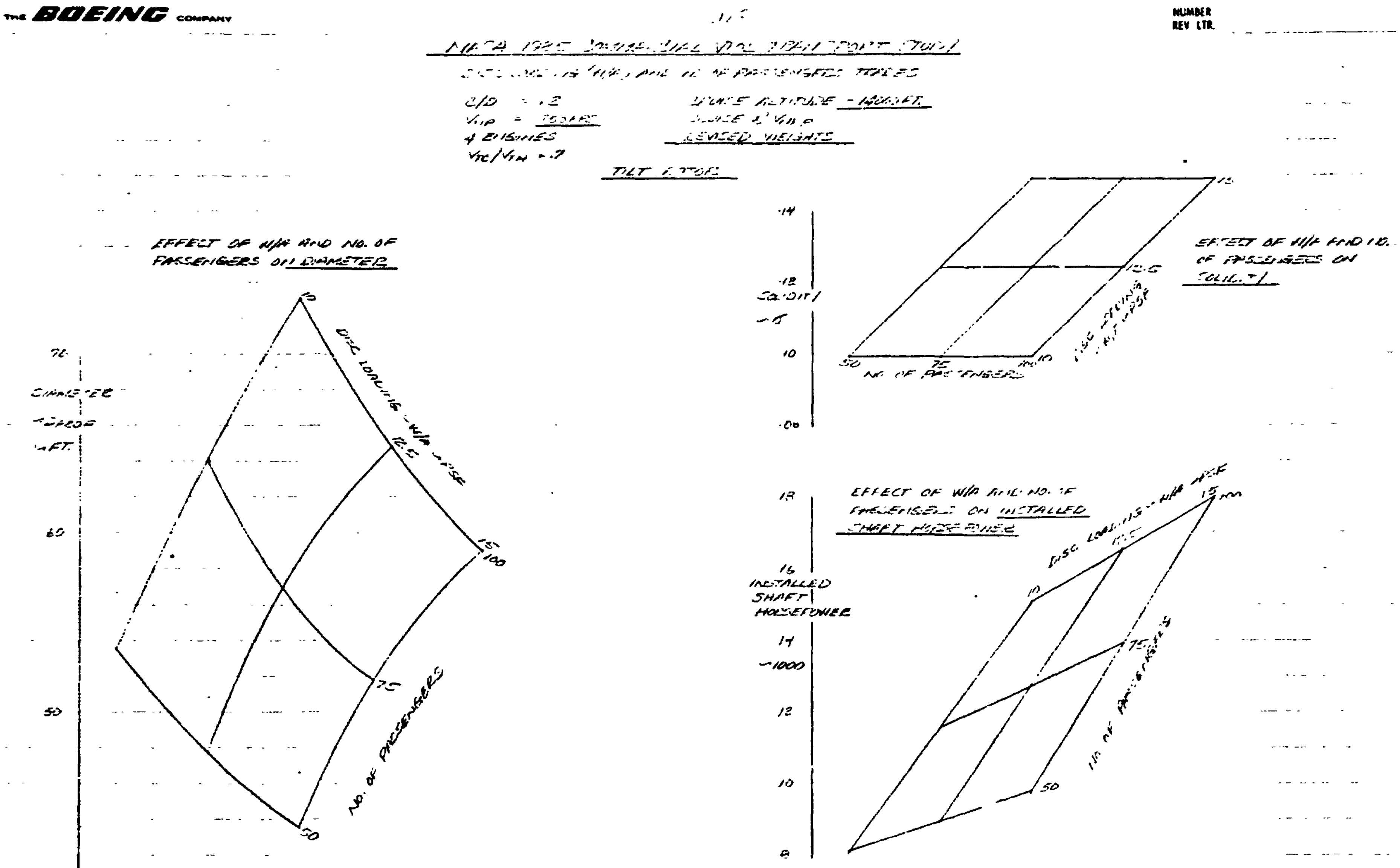

Figure 2.15b. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND NO OF PASSENGERS

C_L/σ = .2
V_{TIP} = 750 FPS
4 ENGINES
V_{TC}/V_{TH} = .7

CRUISE ALTITUDE = 14000 FT.
CRUISE @ V_{MRP}
REVISED WEIGHTS

TILT ROTOR

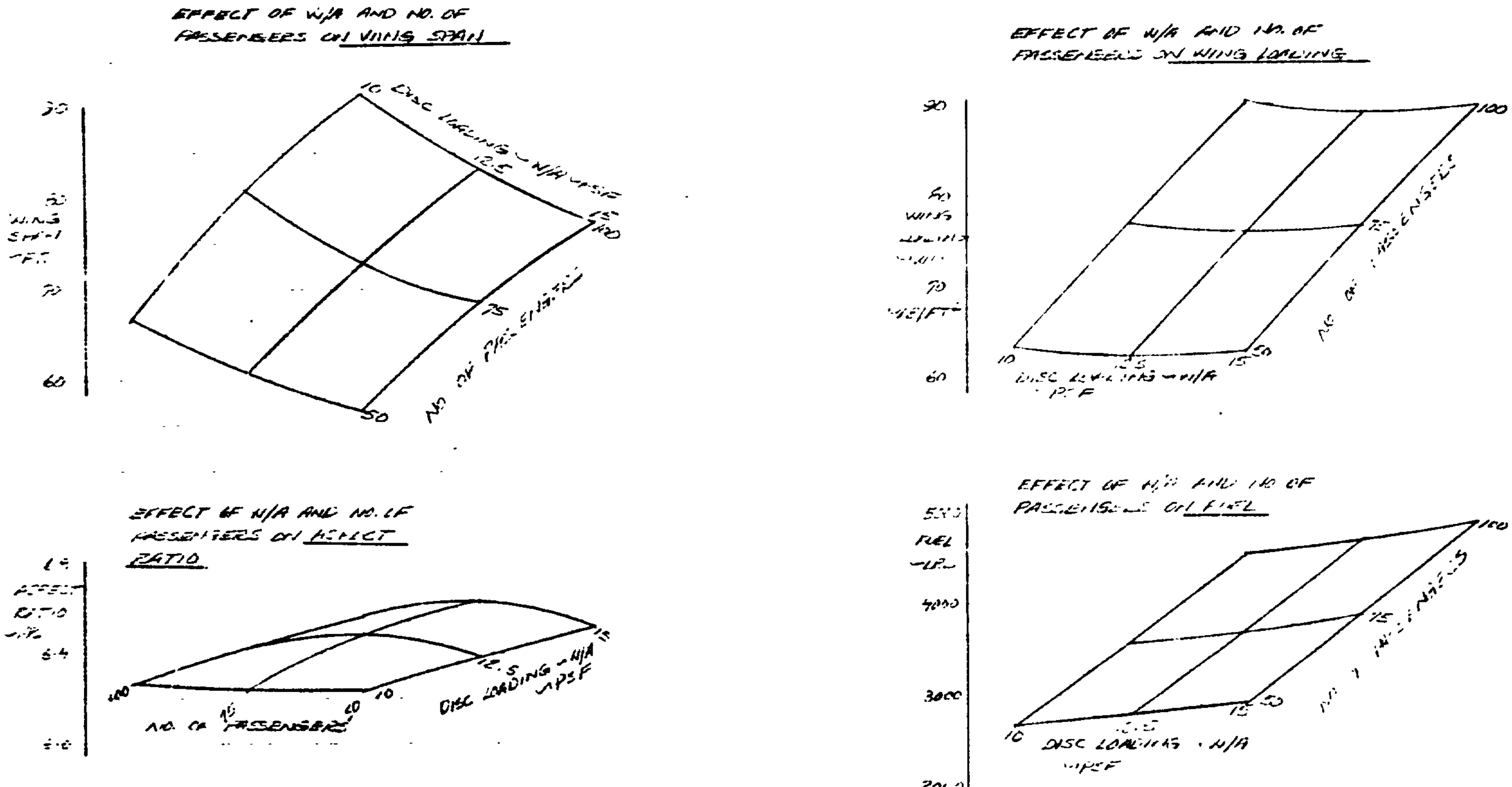

Figure 2.15c. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING AND NO. OF PASSENGERS TRADES

C/C = .2
ENGINES
CRUISE ALTITUDE = 14000 FT
REVISED WEIGHTS

TILT ROTOR

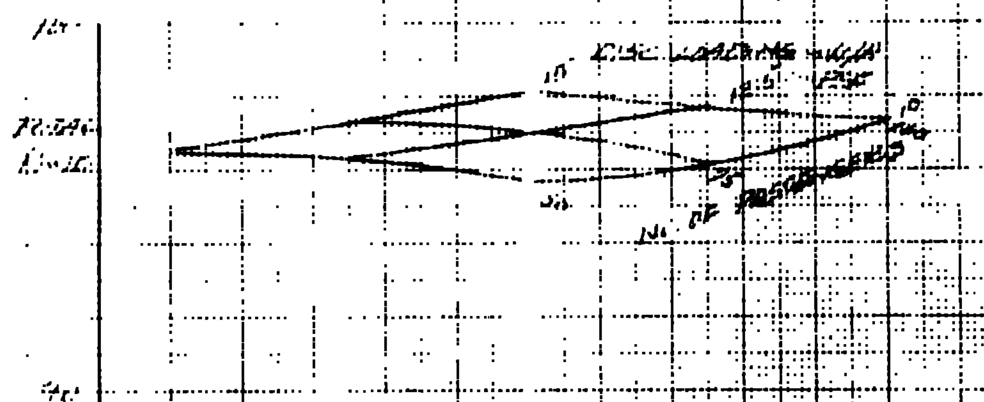


Figure 2.15d. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

DISC LOADING (W/A) AND NO. OF PASSENGERS TRADES

C/L .2	CRUISE ALTITUDE = 14000 FT
V_{TIP} 750 FPS	CRUISE @ V_{MRC}
V_{TIP}/V_H = .7	REVISED WEIGHTS
4 ENGINES	

TILT ROTORS

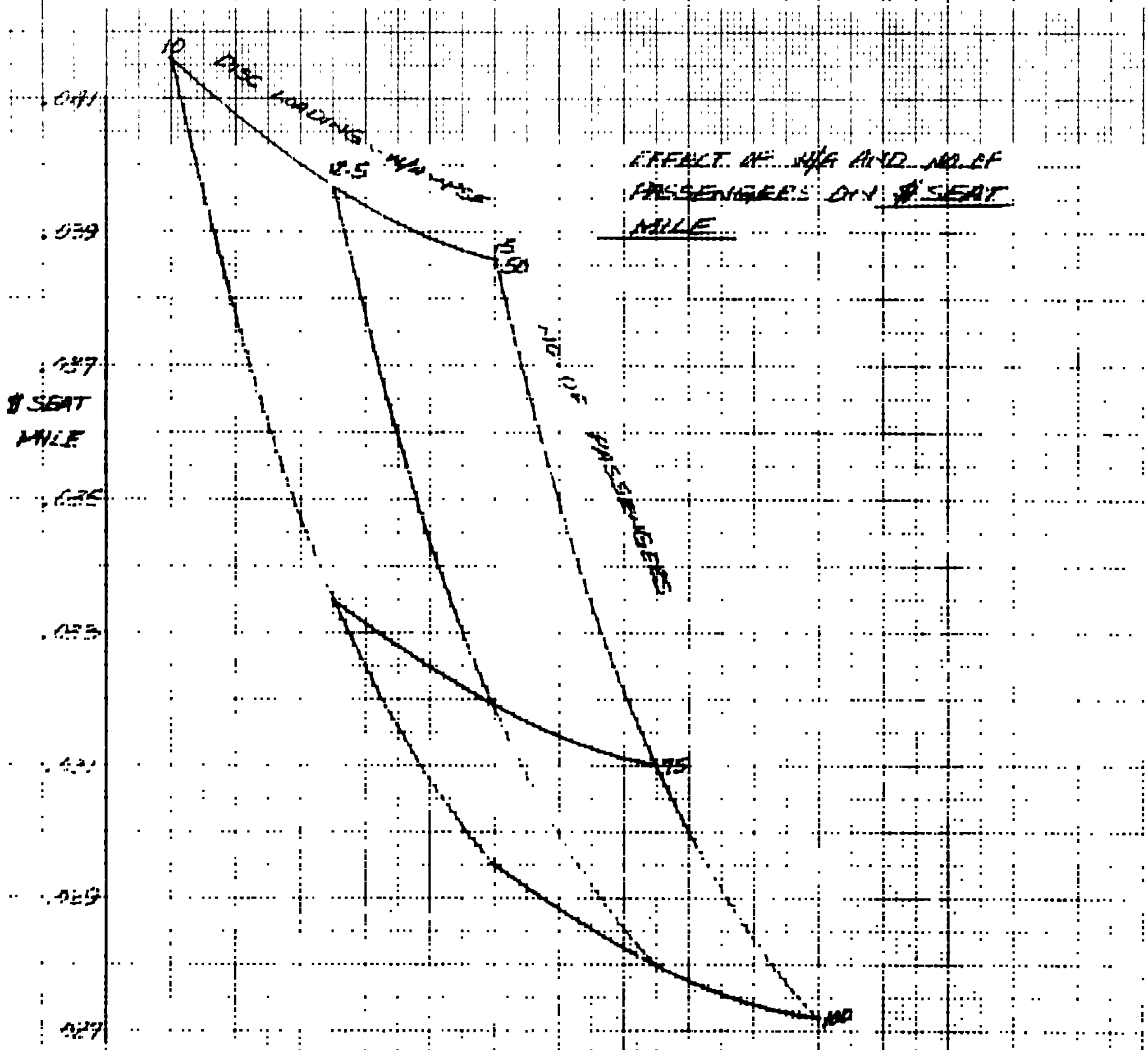
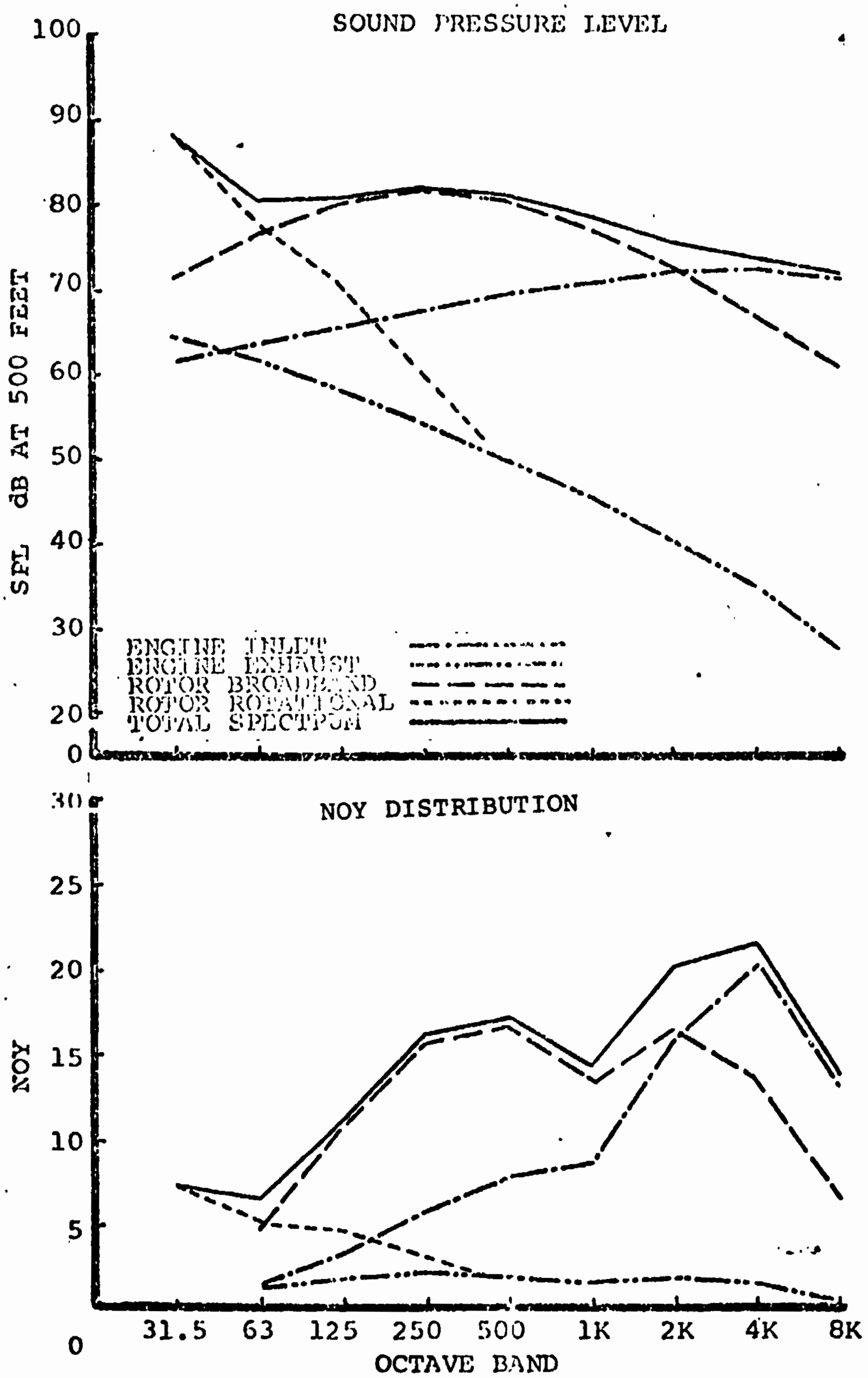
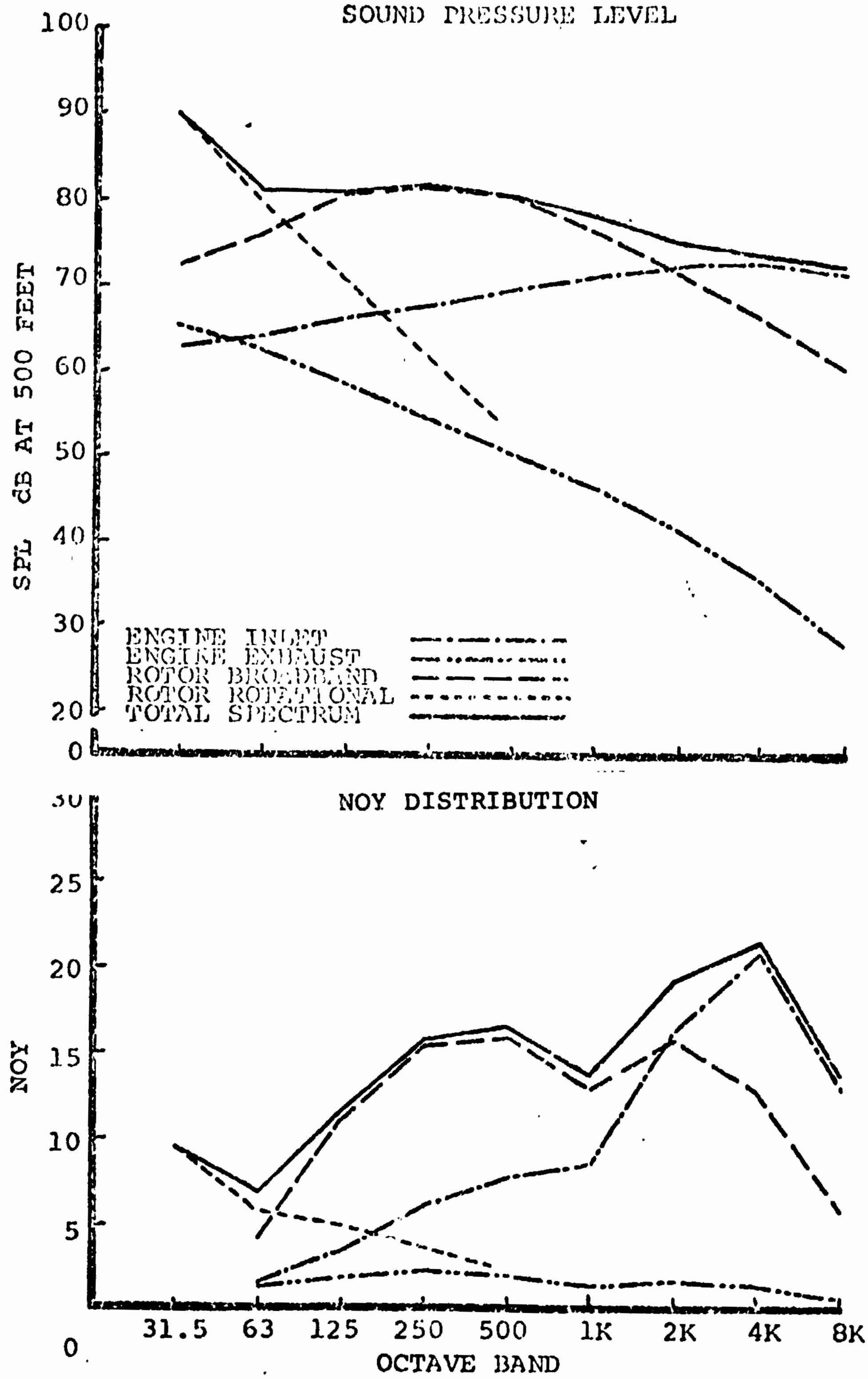


Figure 2.15e. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.



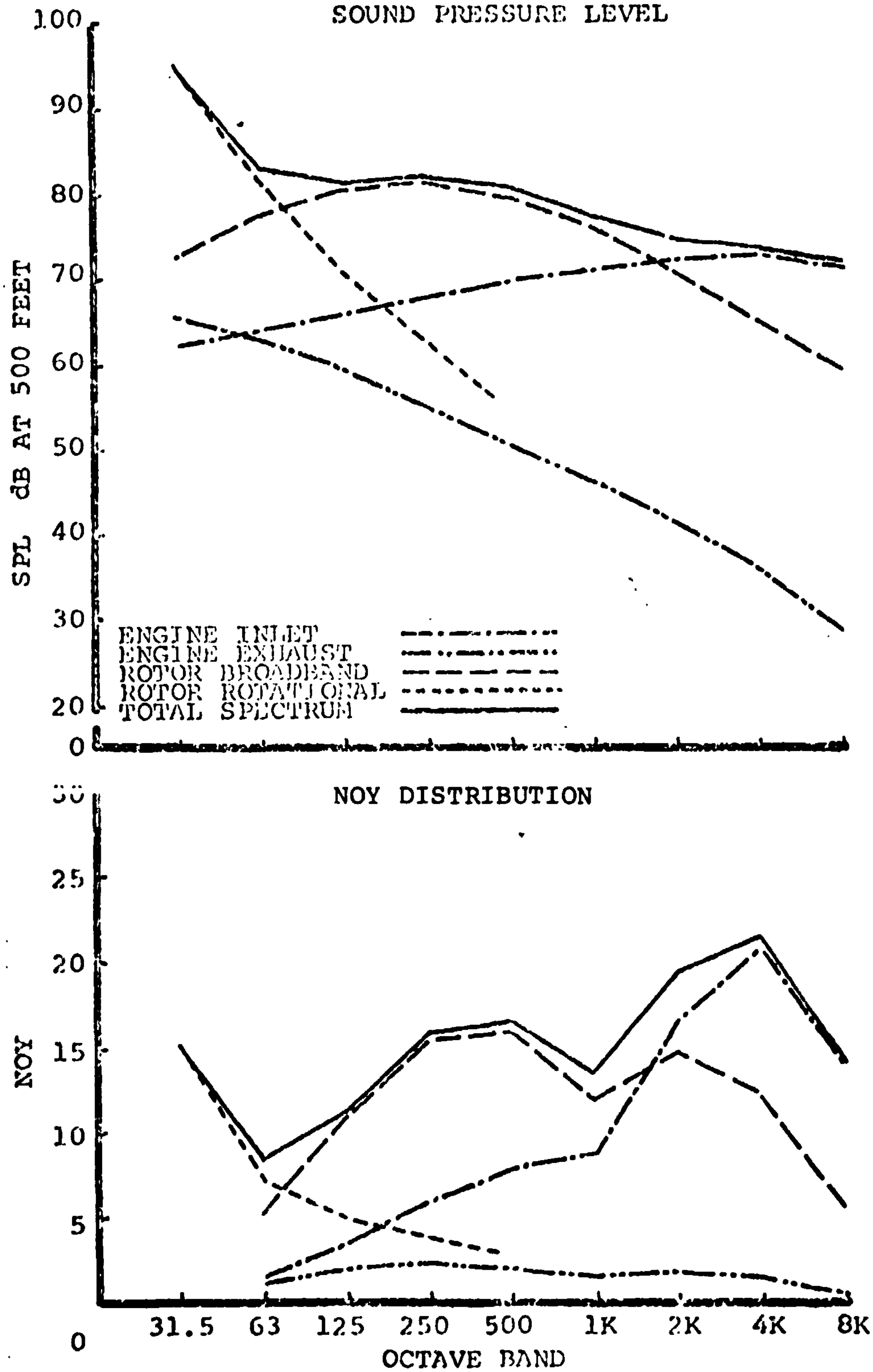
TILT ROTOR, CASE 1, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A = 10, PNdB = 97.5

Figure 2.15f. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.



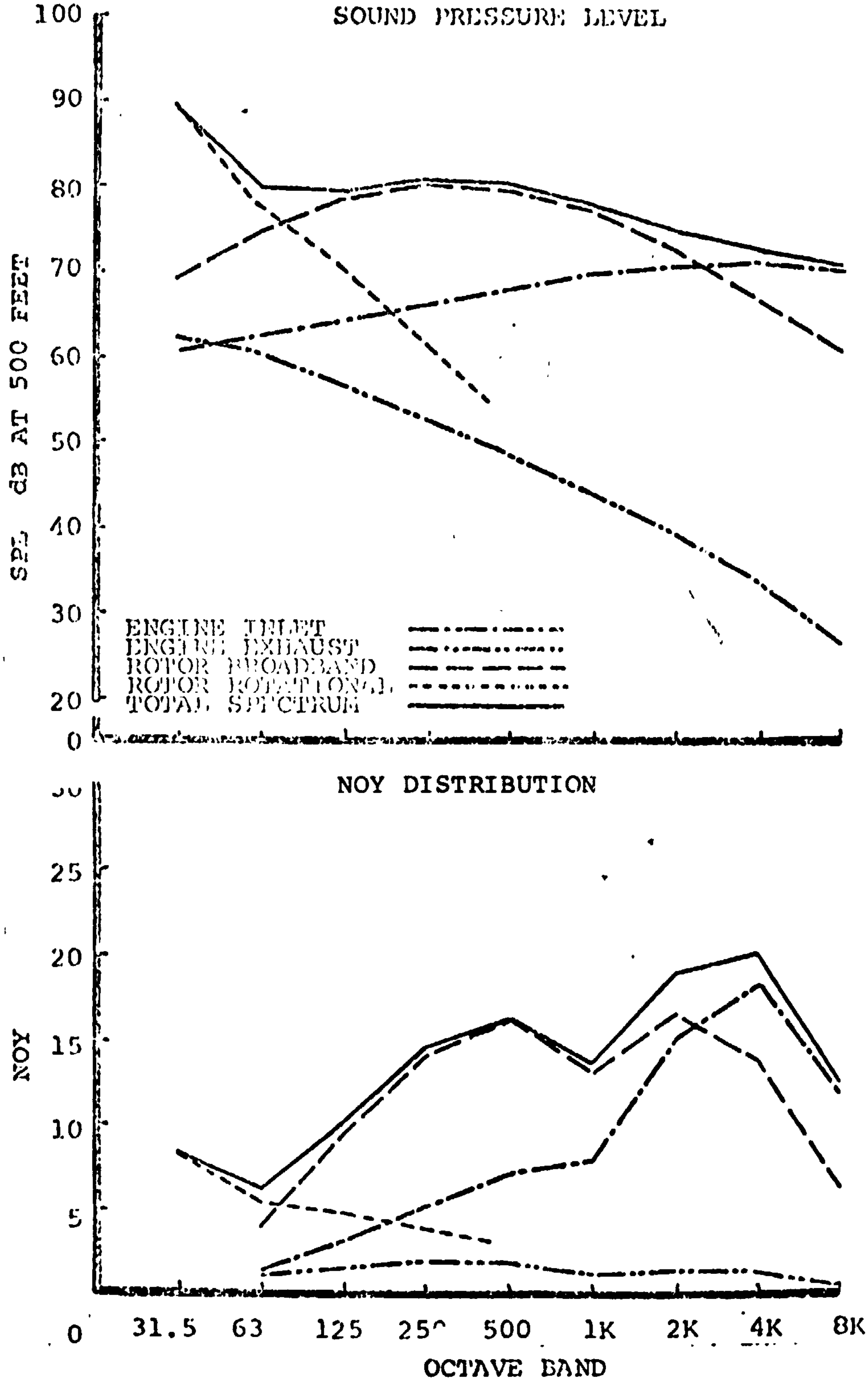
TILT ROTOR, CASE 2, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A = 12.5, PNdB = 97.6

Figure 2.15g. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet. Disc Loading = 12.5 PSF.



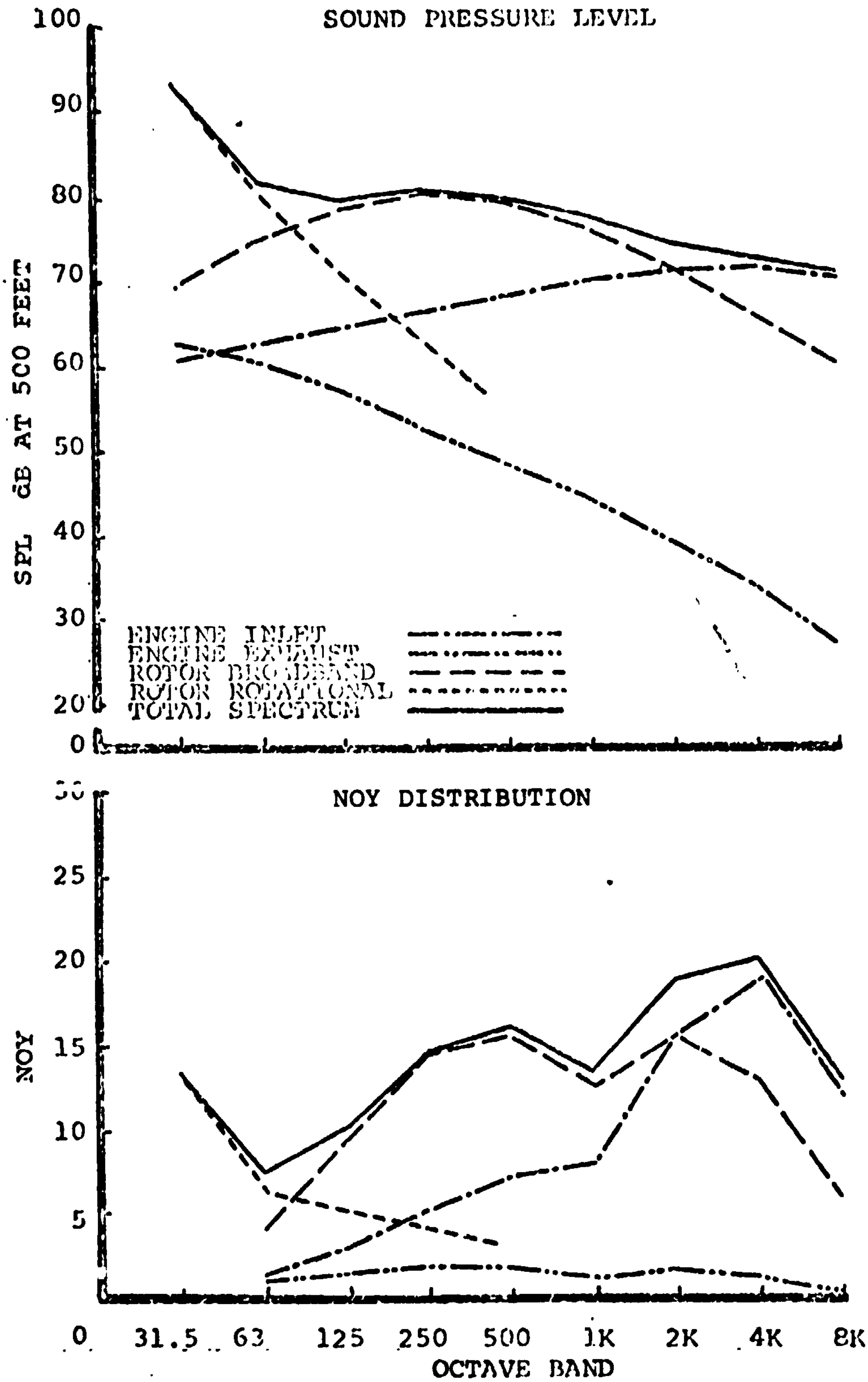
TILT ROTOR, CASE 3, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A = 15, PNdB = 98.2

Figure 2.15h. Tilt Rotor Number of Passenger Trade. Altidue = 14,000 Feet.



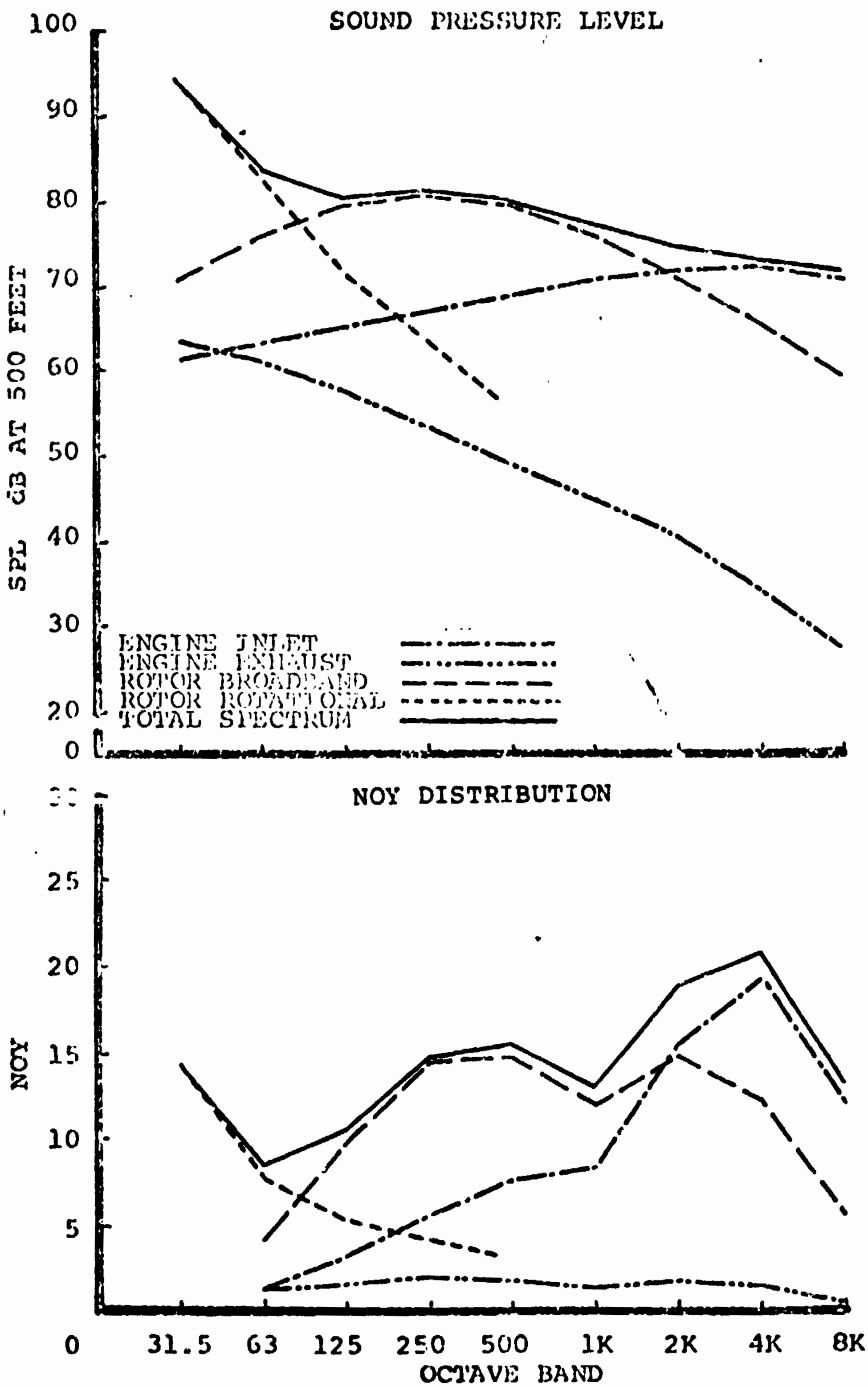
7 TILT ROTOR, CASE 4, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 75 PASSENGERS, VT = 750, W/A = 10, PNdB = 96.6

Figure 2.15i. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.



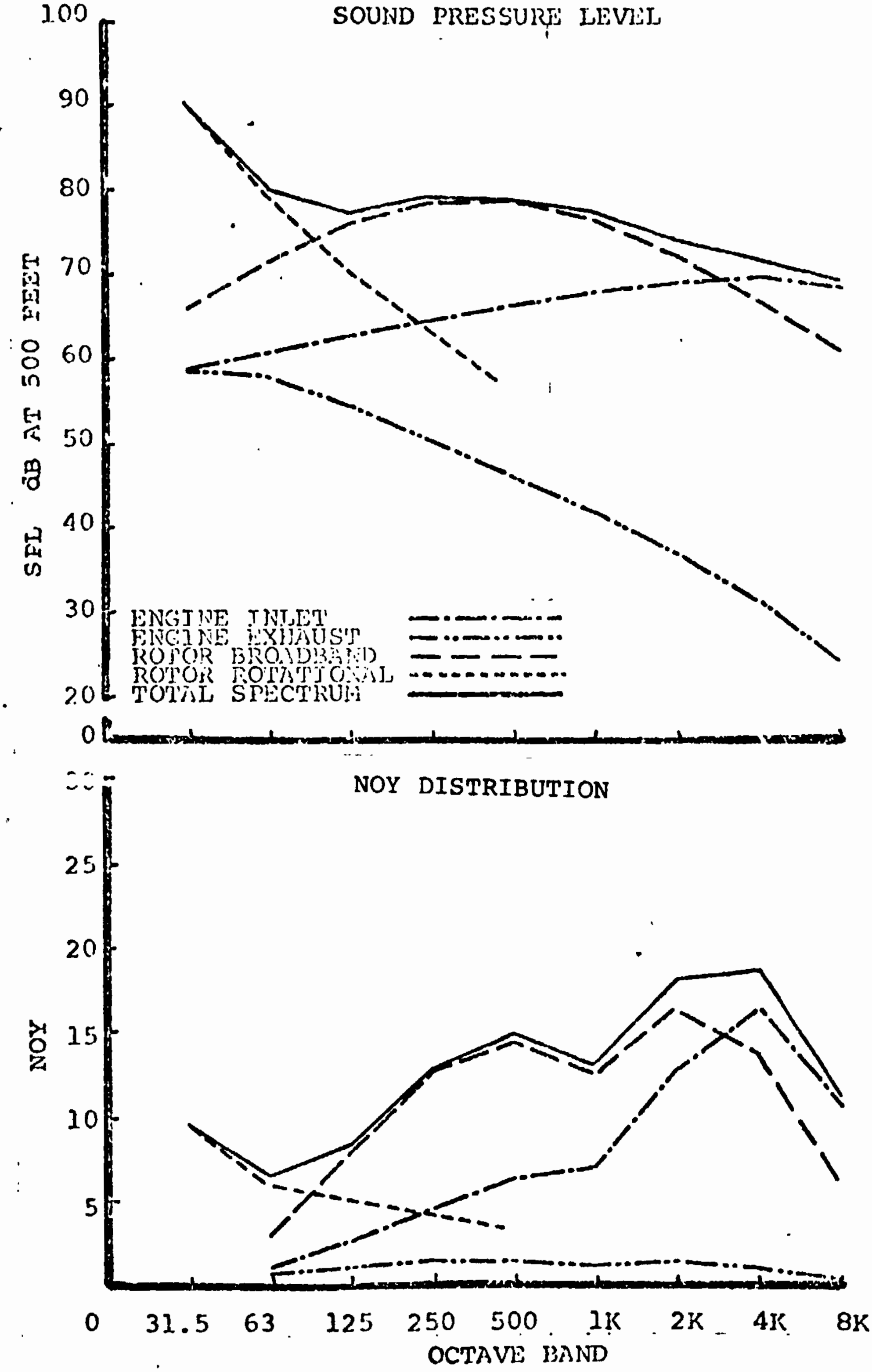
TILT ROTOR, CASE 5, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 75 PASSENGERS, VT = 750, W/A = 12.5, PNdB = 97.1

Figure 2.15j. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet. Disc Loading = 12.5 PSF.



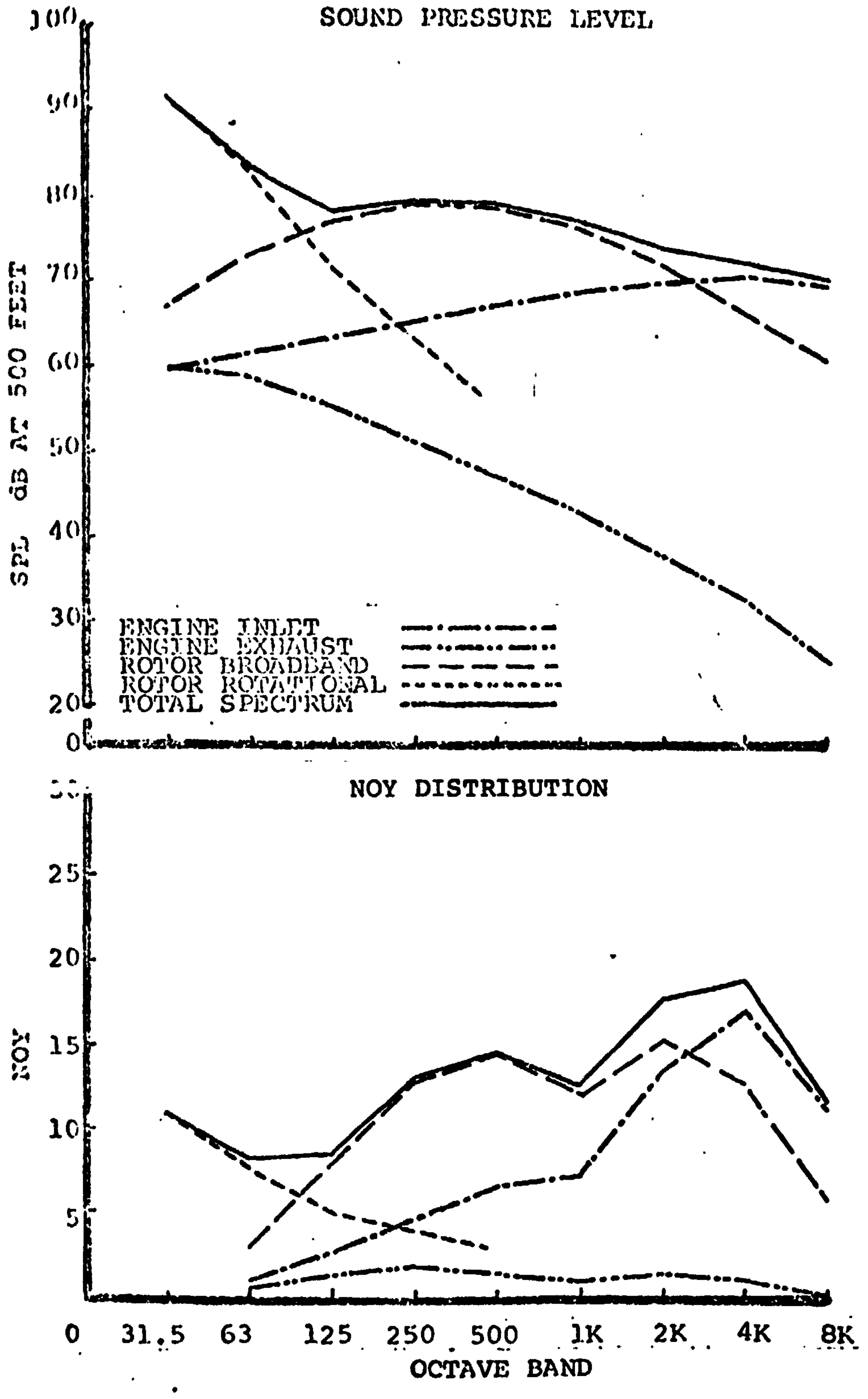
TILT ROTOR, CASE 6, HOVER NOISE, SPECTRUM AND NOY DISTRIBUTION, 75 PASSENGERS, VT = 750, W/A = 15, PNdB = 97.5

Figure 2.15k. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.



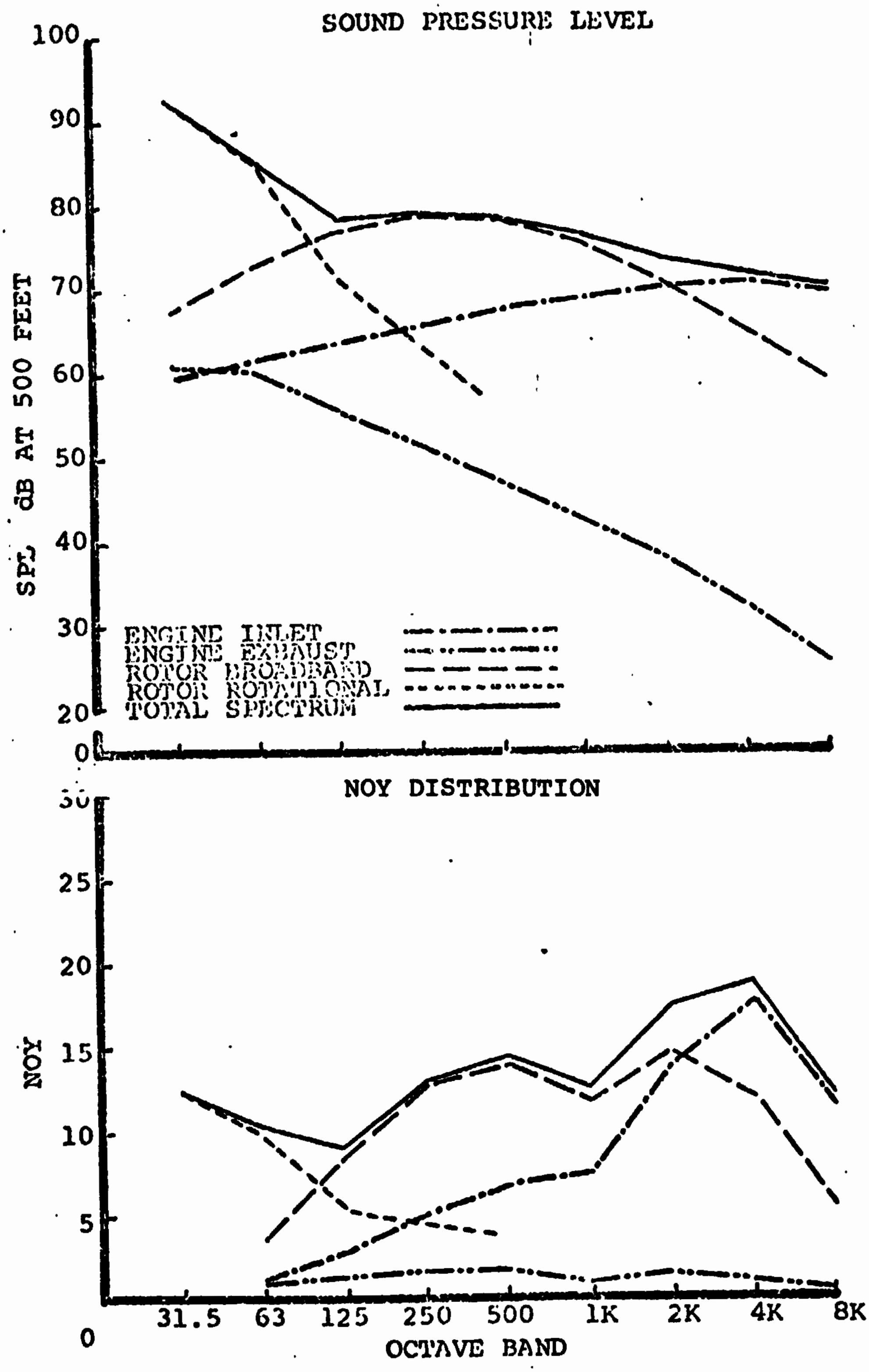
TILT ROTOR, CASE 7, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 50 PASSENGERS, VT = 750, W/A = 10, PNdB = 95.7

Figure 2.151. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.



TILT ROTOR, CASE 8, HOVER NOISE PSECTRUM AND NOY DISTRIBUTION, 50 PASSENGERS, VT = 750, W/A = 12.5, PNdB = 95.9

Figure 2.15m. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet. Disc Loading = 12.5 PSF.



TILT ROTOR, CASE 9, HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 50 PASSENGERS, VT = 750, W/A = 15

Figure 2.15n. Tilt Rotor Number of Passenger Trade. Altitude = 14,000 Feet.

NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

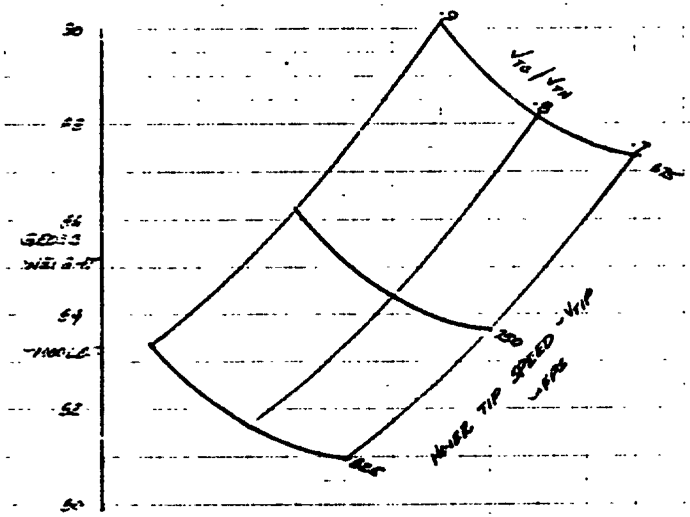
HOVER TIP SPEED (V_{TIP}) AND V_{TC}/V_{TH} TRADES

NO OF PASS = 100
SEATS ACROSS = 7
C/D = .2
W/A = 12.5 PSF

4 ENGINES
CRUISE ALTITUDE = 14000 FT
CRUISE @ V_{NCP}

TILT ROTOR

EFFECT OF V_{TIP} AND V_{TC}/V_{TH} ON GROSS WEIGHT



EFFECT OF V_{TIP} AND V_{TC}/V_{TH} ON WEIGHT EMPTY

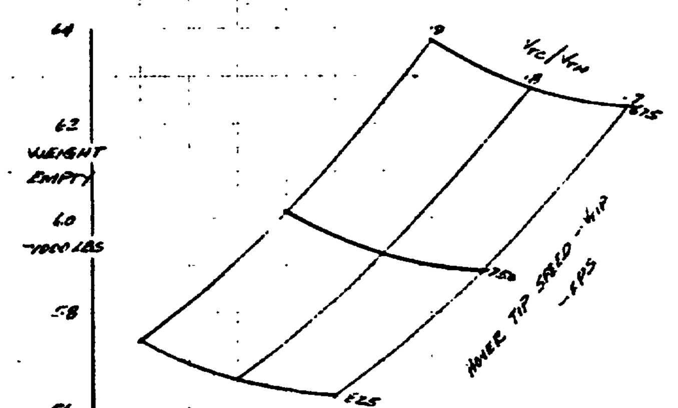


Figure 2.16a. Tilt Rotor Cruise Tipspeed Reduction Trade. 100 Passenger. Altitude = 14,000 Feet. Disc Loading = 12.5 PSF.

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TILT ROTOR

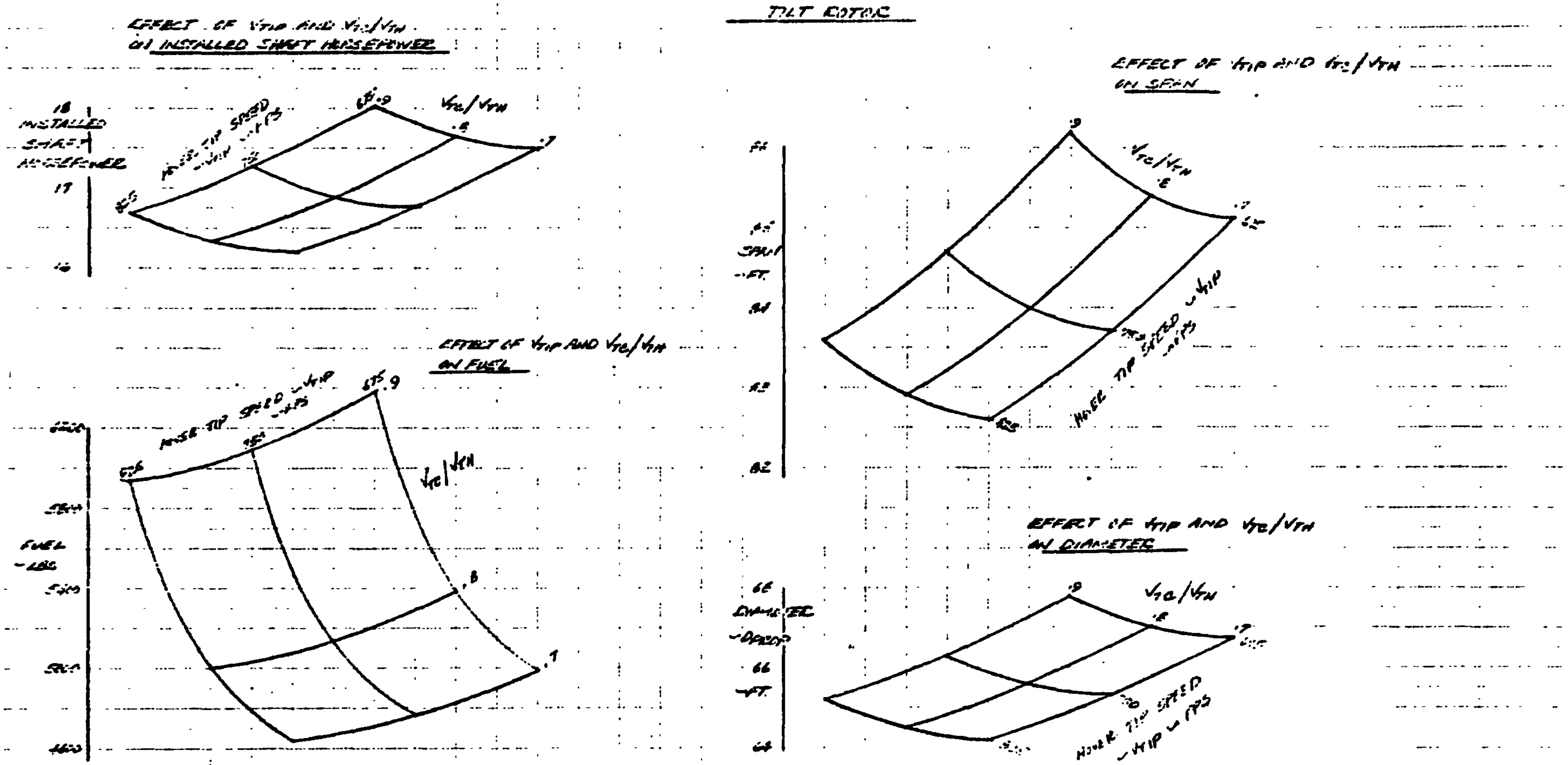

Figure 2.16b. Tilt Rotor Cruise Tipspeed Reduction Trade. 100 Passenger. Altitude = 14,000 Feet. Disc Loading = 12.5 PSF.

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NASA 1985 COMMERCIAL VTOL TRANSPORT STUDY

HOVER TIP SPEED (V_{TIP}) AND V_{TC}/V_{TH} TRADES

NO. OF PASS = 100
SEATS ACROSS = 7
C/D = .2
W/A = 12.5 PSF

4 ENGINES
CRUISE ALTITUDE = 14,000 FT
CRUISE @ V_{MCP}

TILT ROTOR

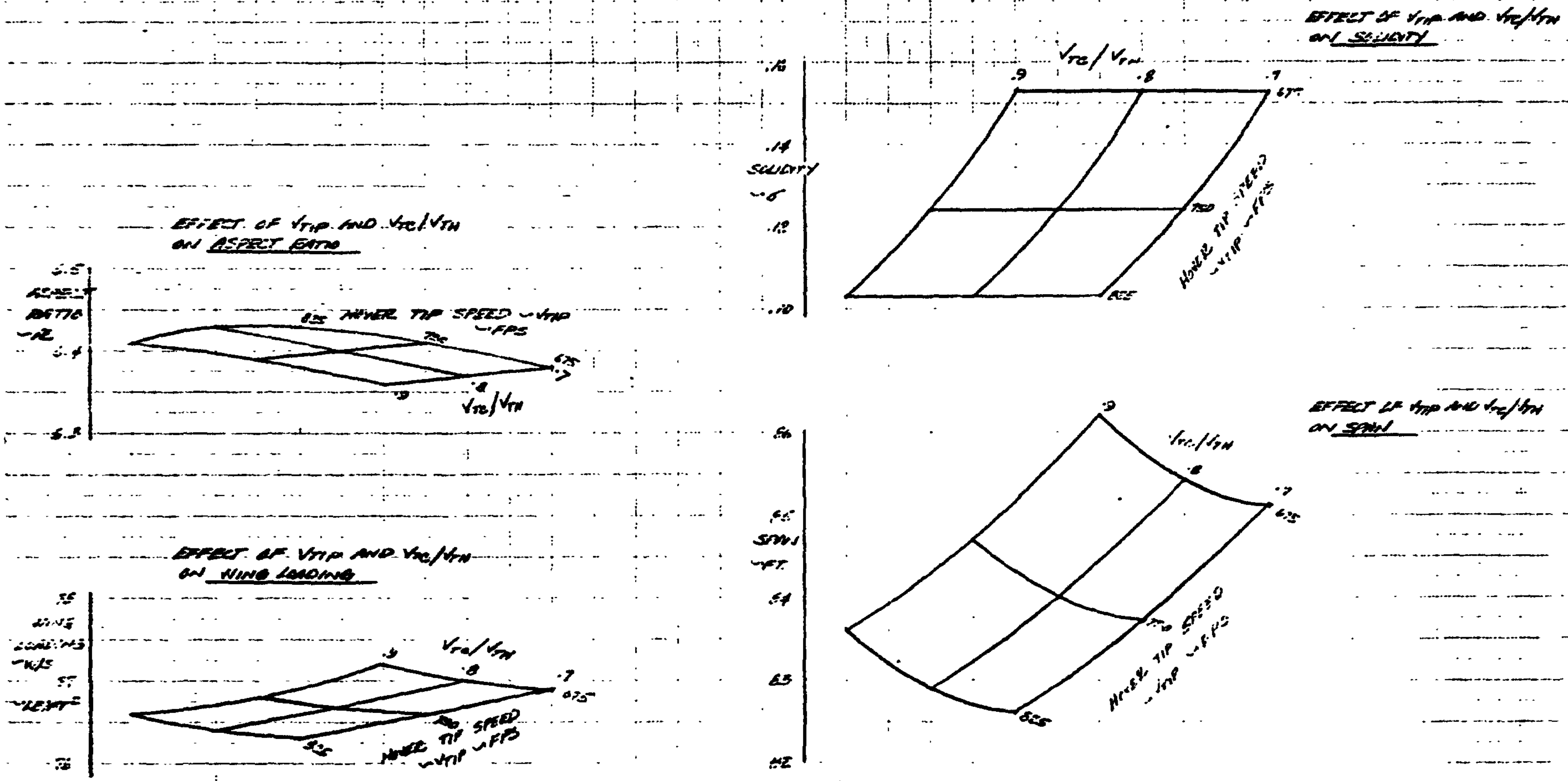

Figure 2.16c. Tilt Rotor Cruise Tipspeed Reduction Trade. 100 Passenger. Altitude = 14,000 Feet. Disc Loading= 12.5 PSF.

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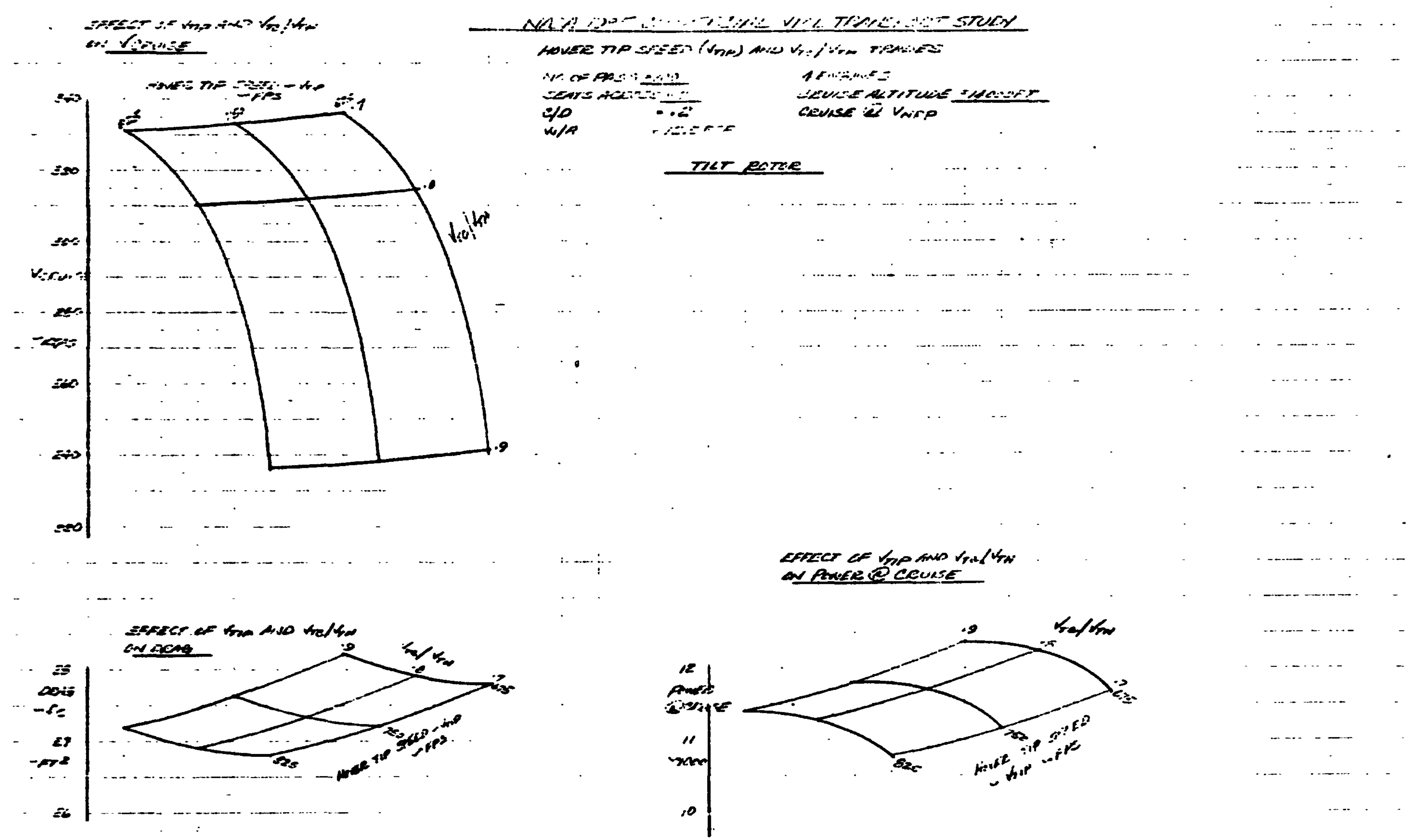

Figure 2.16d. Tilt Rotor Cruise Tipspeed Reduction Trade. 100 Passenger. Altitude = 14,000 Feet. Disc Loading = 12.5 PSF.

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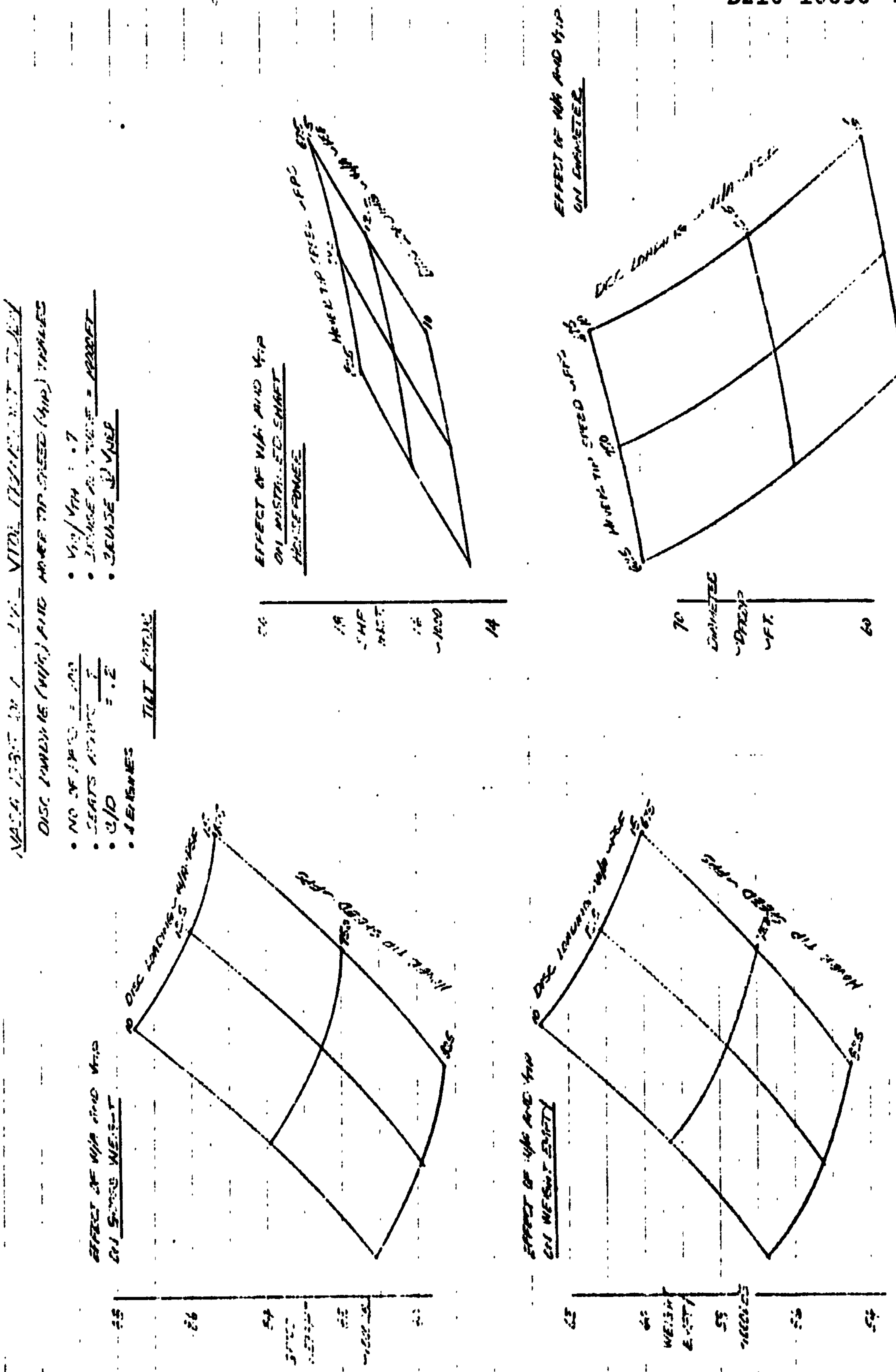

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Figure 2.17a. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Ft.

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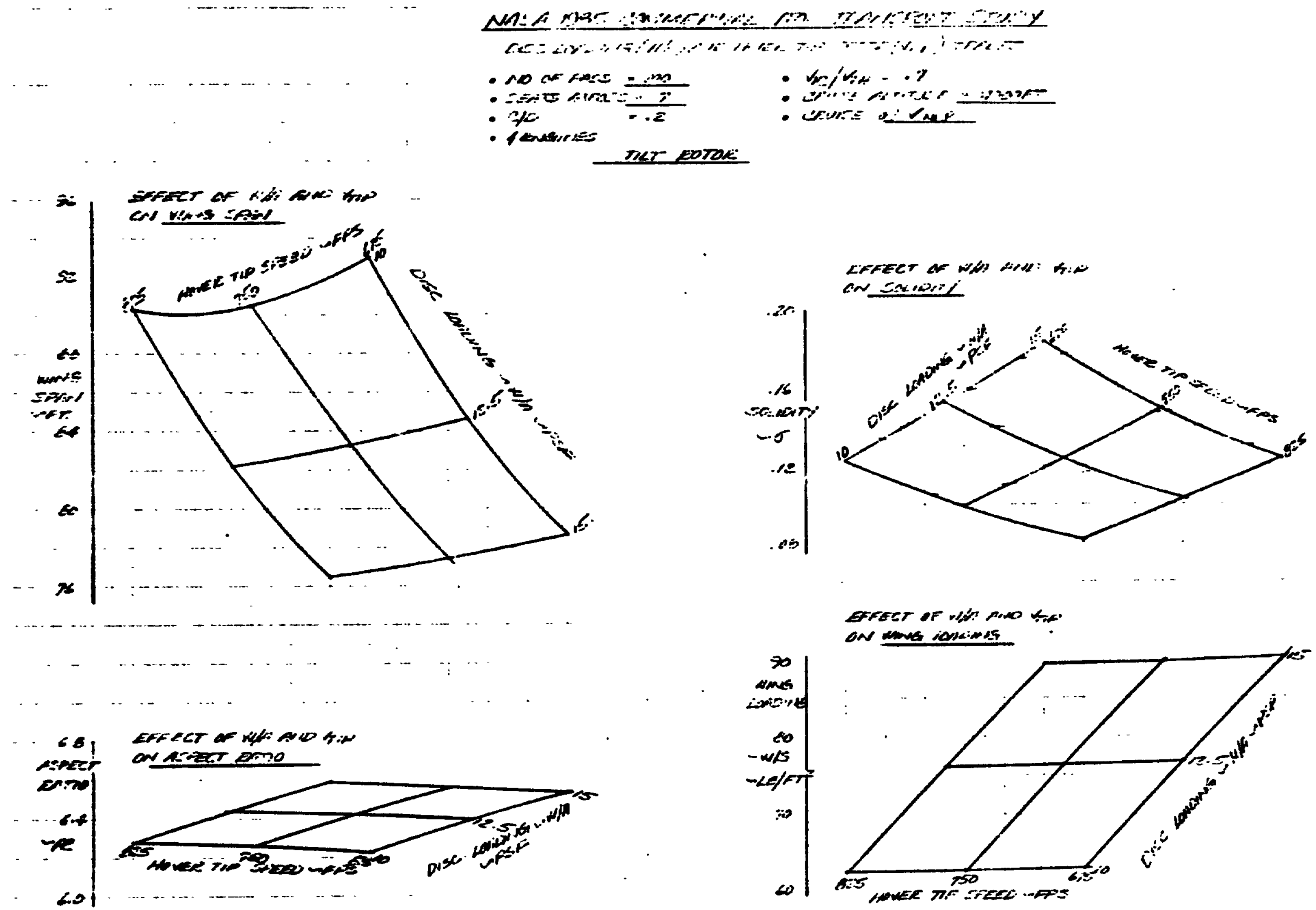

Figure 2.17b. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.

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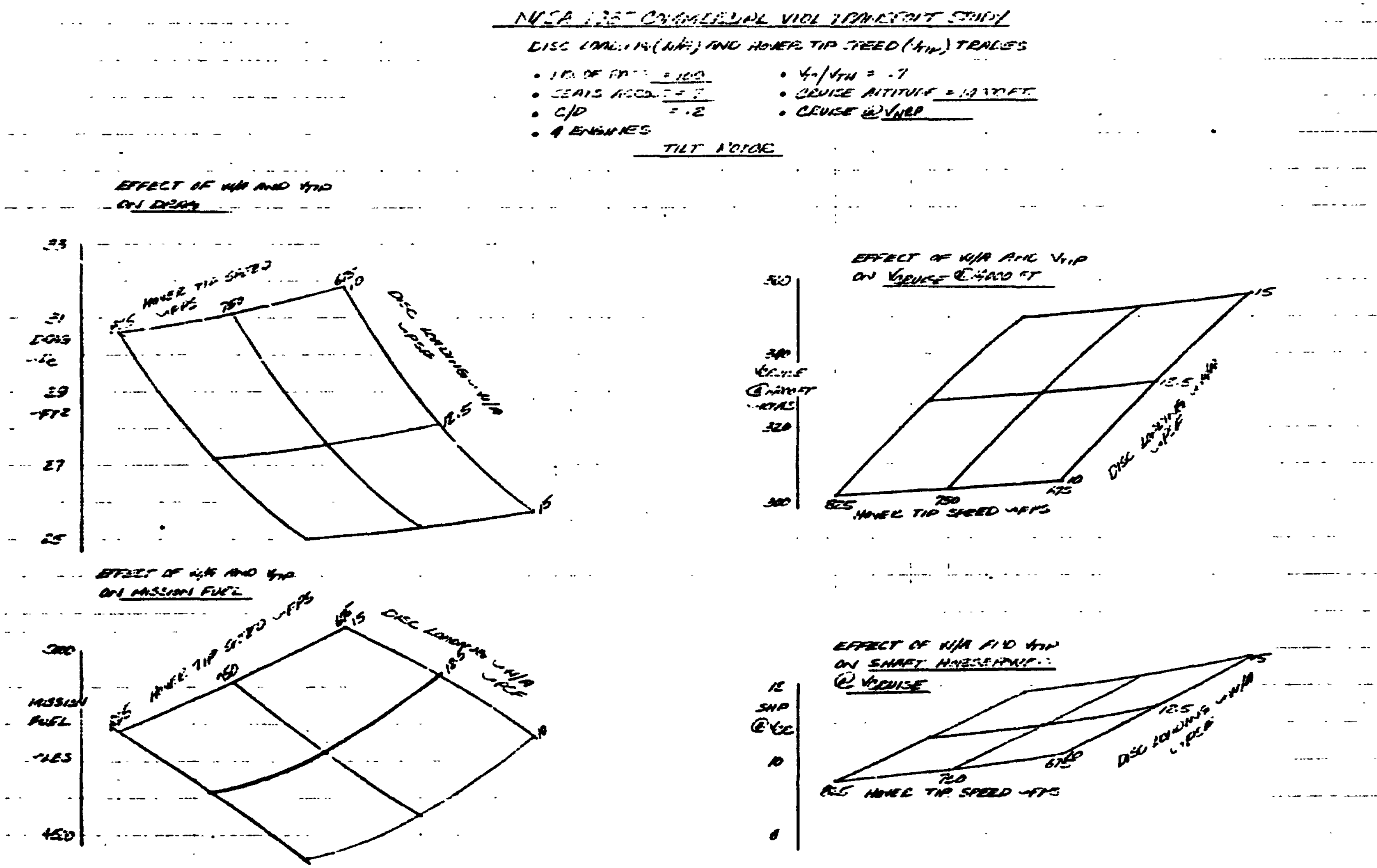

Figure 2.17c. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.

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NASA 1985 Commercial VTOL Transport Study

Disc Loading (W/A) and Hover Tip Speed (Vtip) Trades

No. of Pass = 100
Seats Across = 7
C/D = .2
4 Engines

Vtip/Vtip = .7
Cruise Altitude = 20,000 FT
Cruise @ Vmax

Tilt Rotor

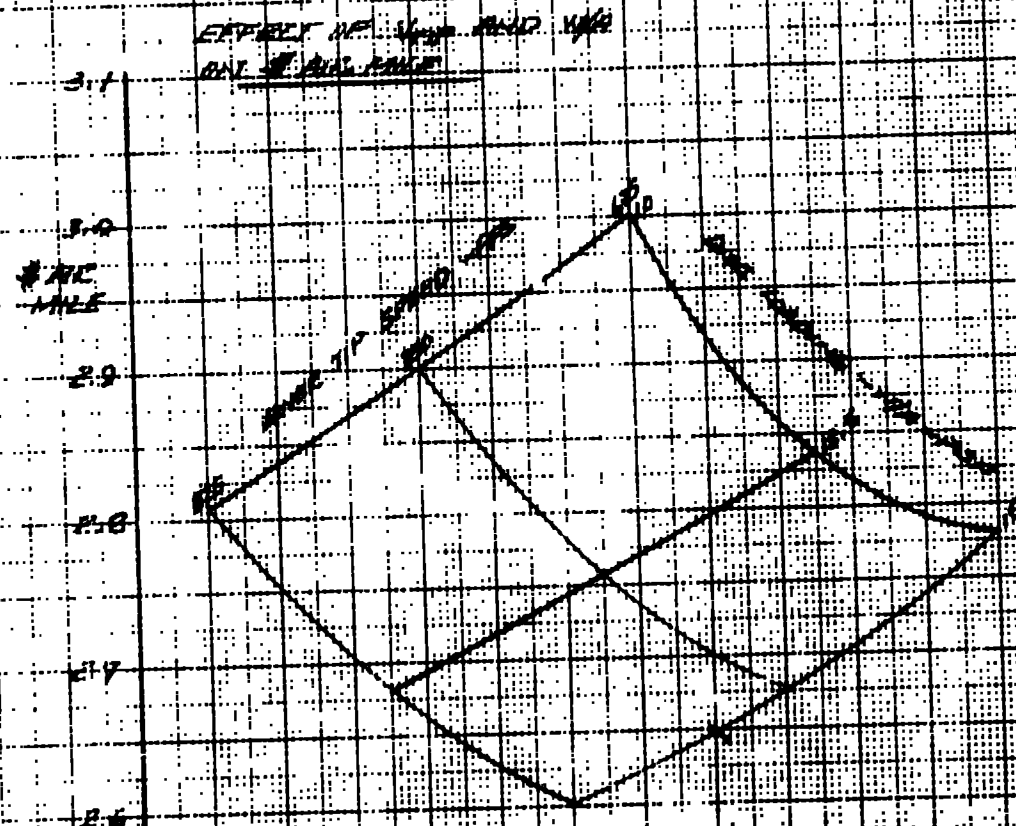

Figure 2.17d. Tilt Rotor Disc Loading and [illegible] Trends. 100 Passengers. Altitude = [illegible] Feet.

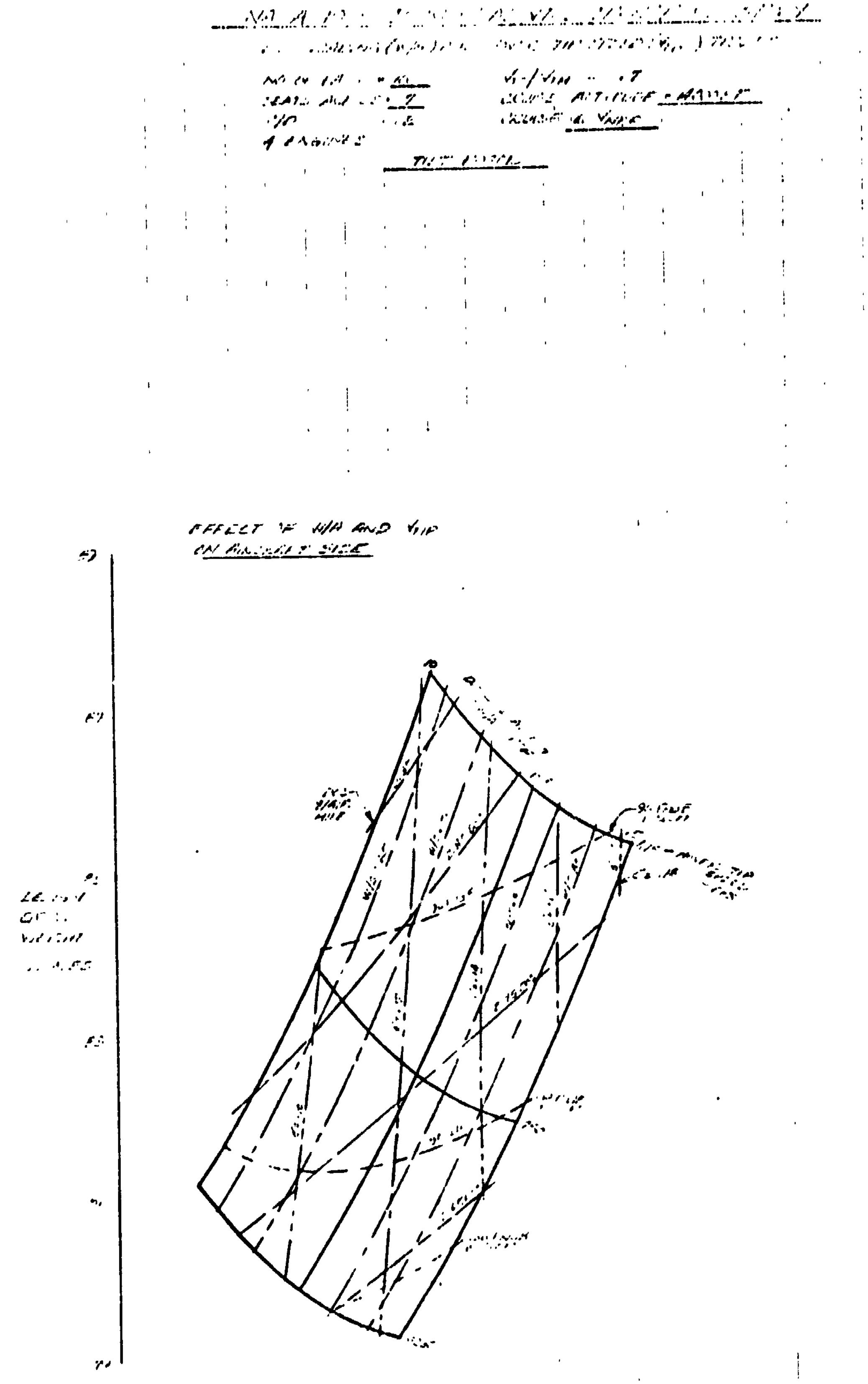

Figure 2.17e. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.

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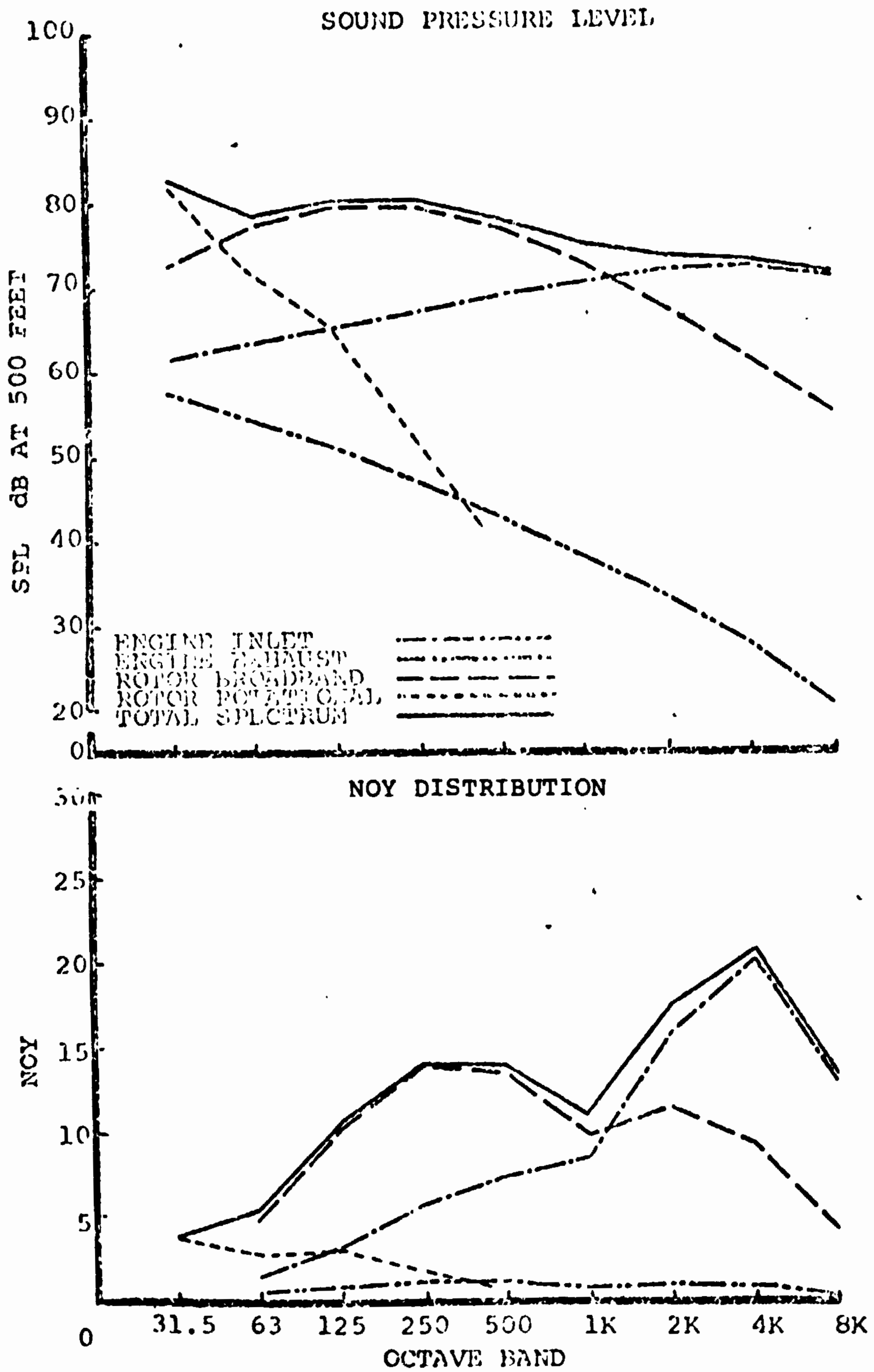

TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 675, W/A = 10, PNdB = 95.9

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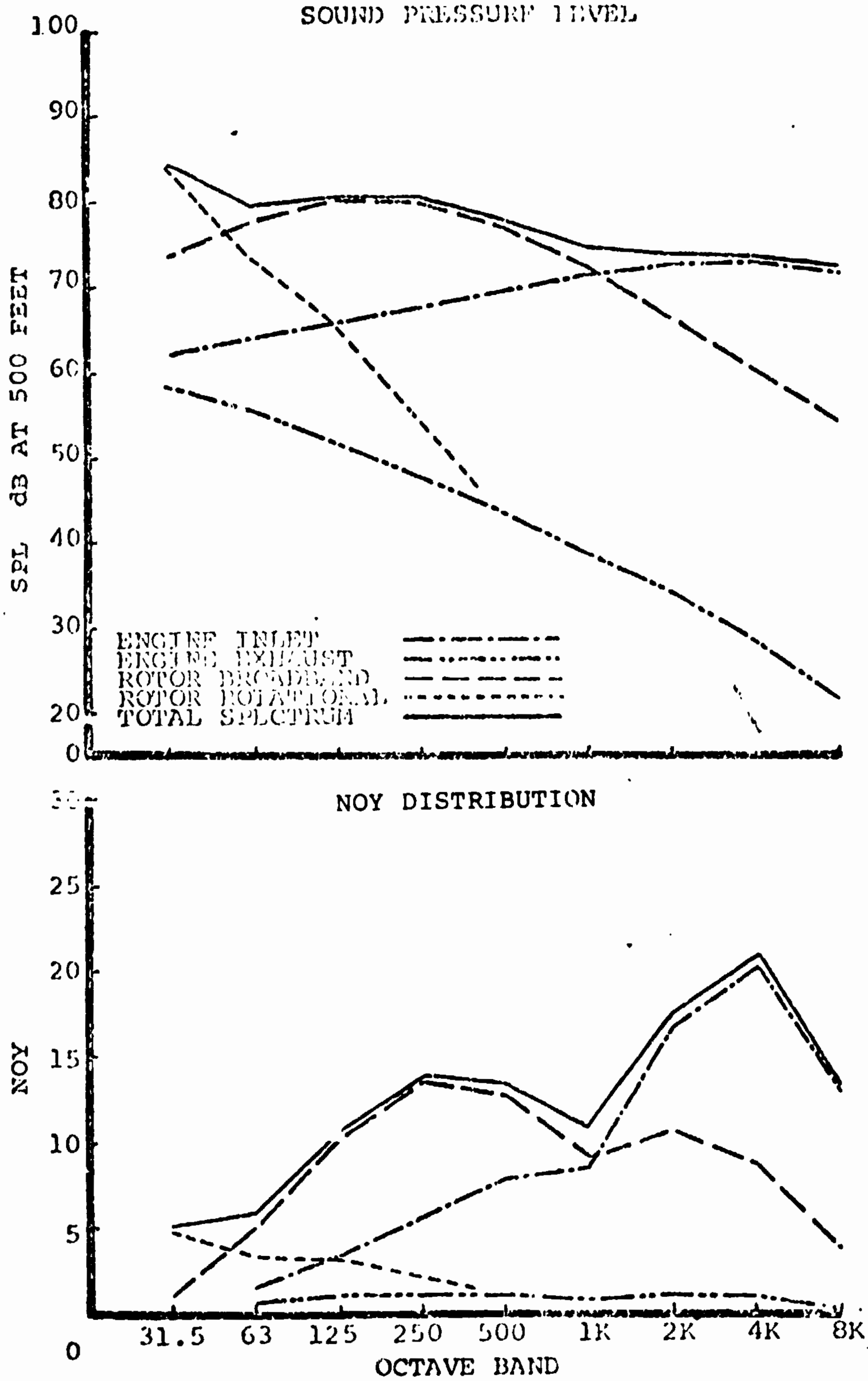
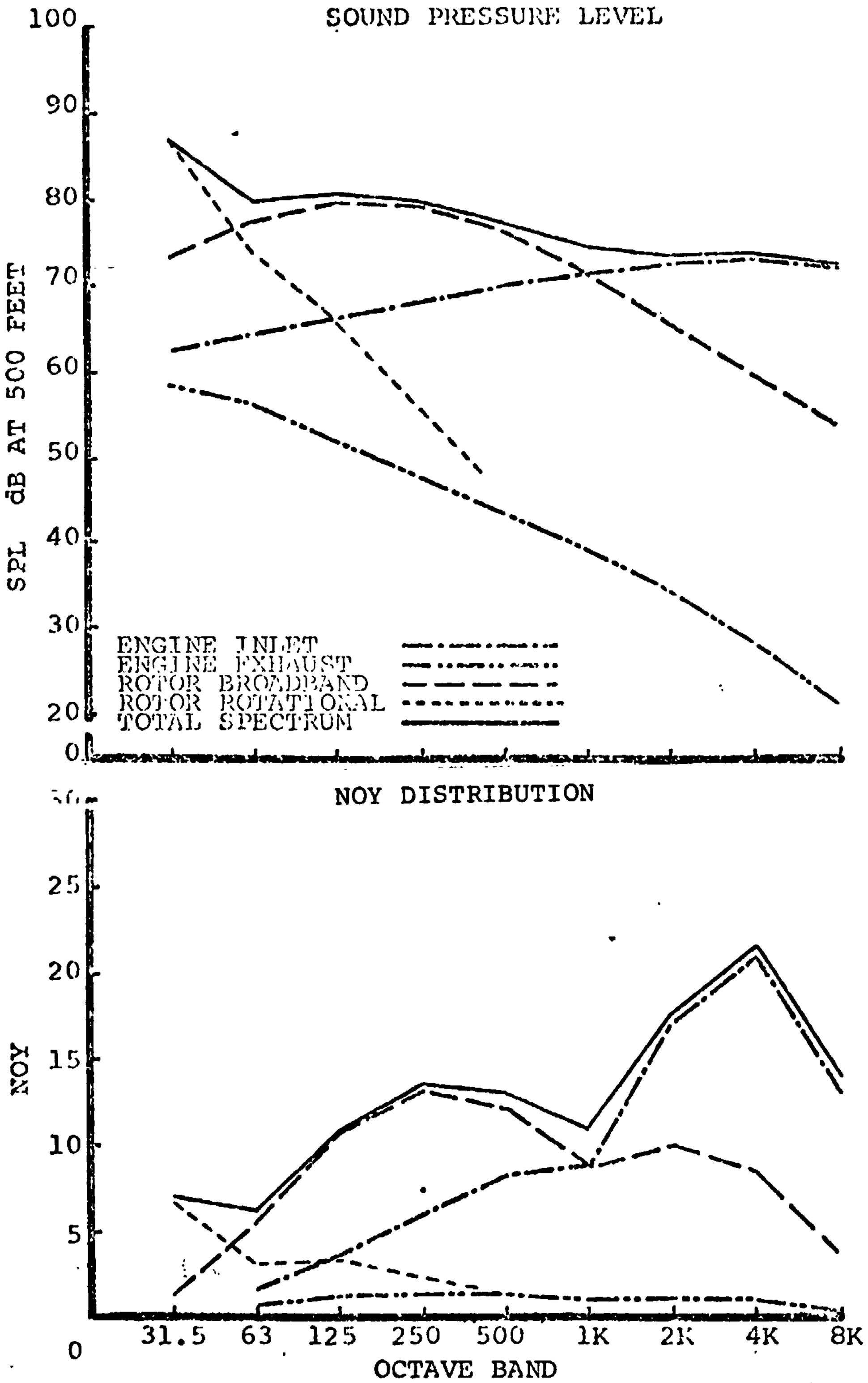
Figure 2.17g. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.



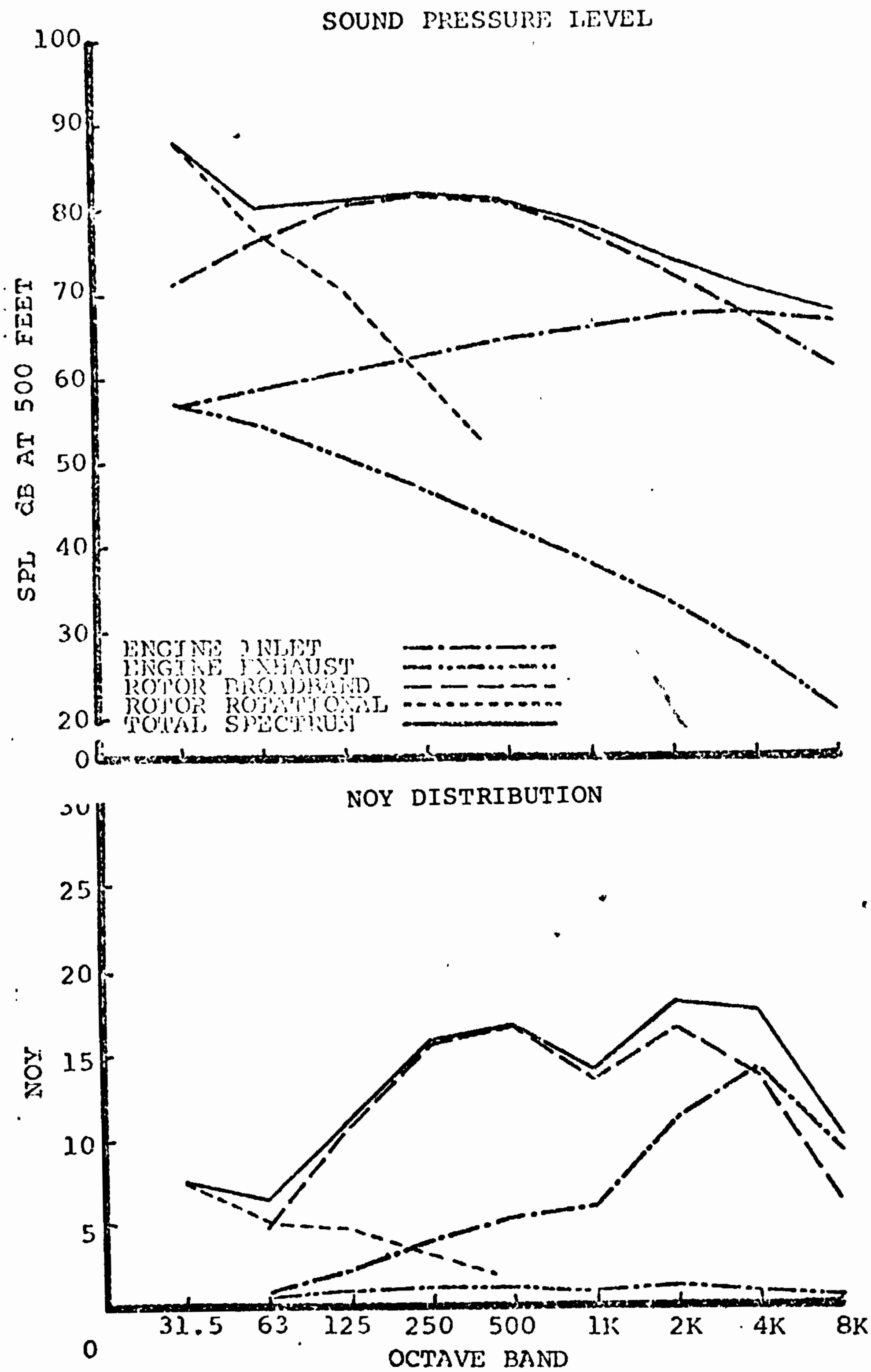
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 675, W/A = 12.5, PNdB = 96

Figure 2.17h. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.



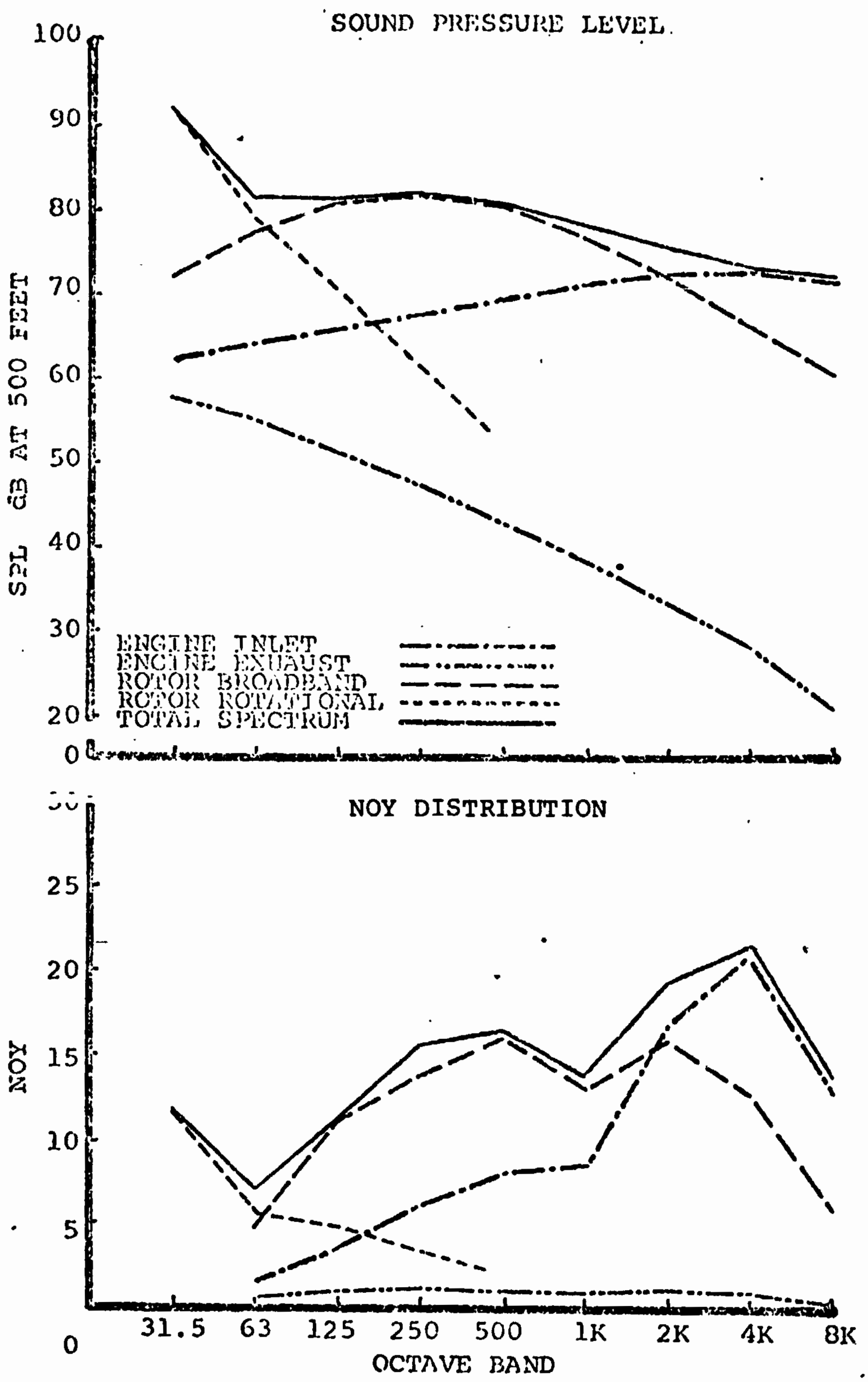
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 675, W/A = 15, PNdB = 96.4

Figure 2.17i. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.



TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 750, W/A = 10, PNdB = 95.9

Figure 2.17j. Tilt Rotor Disc Loading and Tipspeed Trade.
100 Passengers. Altitude = 14,000 Feet.



TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 750, W/A = 12.5, PNdB = 97.8

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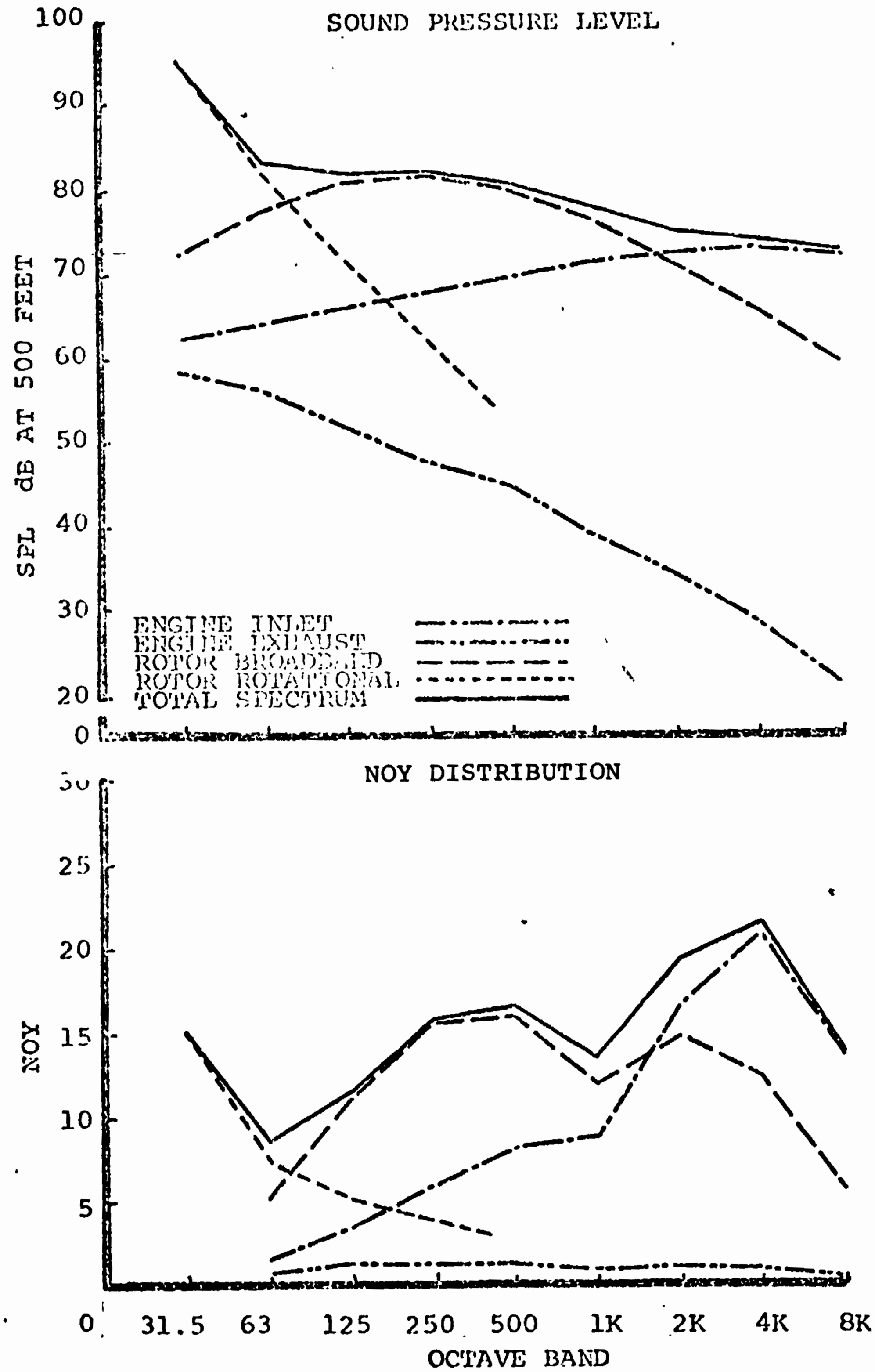
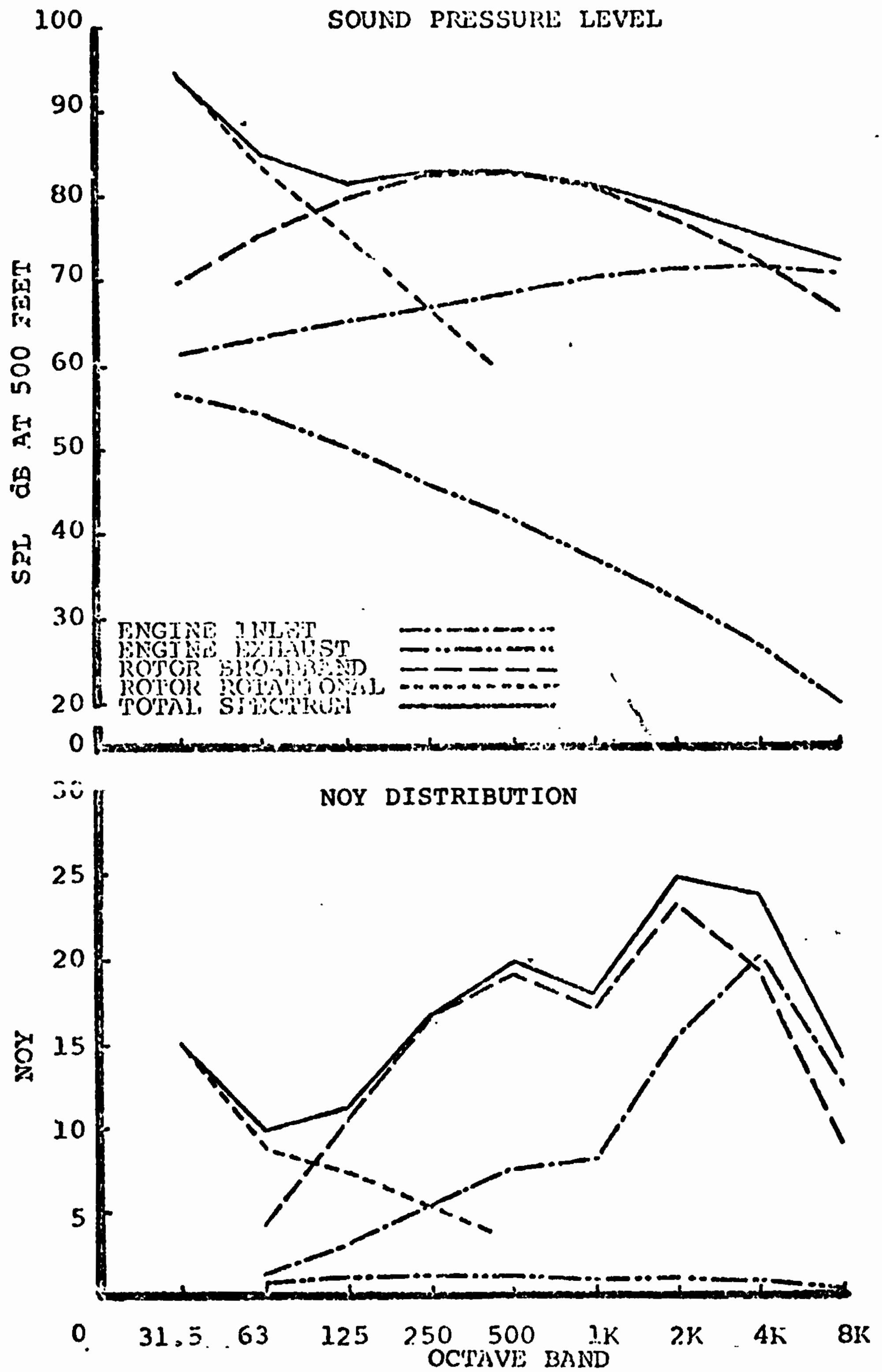
Figure 2.17k. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.



TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 750, W/A = 15, PNdB = 98.2

Figure 2.171. Tilt Rotor Disc Loading and Tipspeed Trade.
100 Passengers. Altitude = 14,000 Feet.



TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 825, W/A = 10, PNdB = 100

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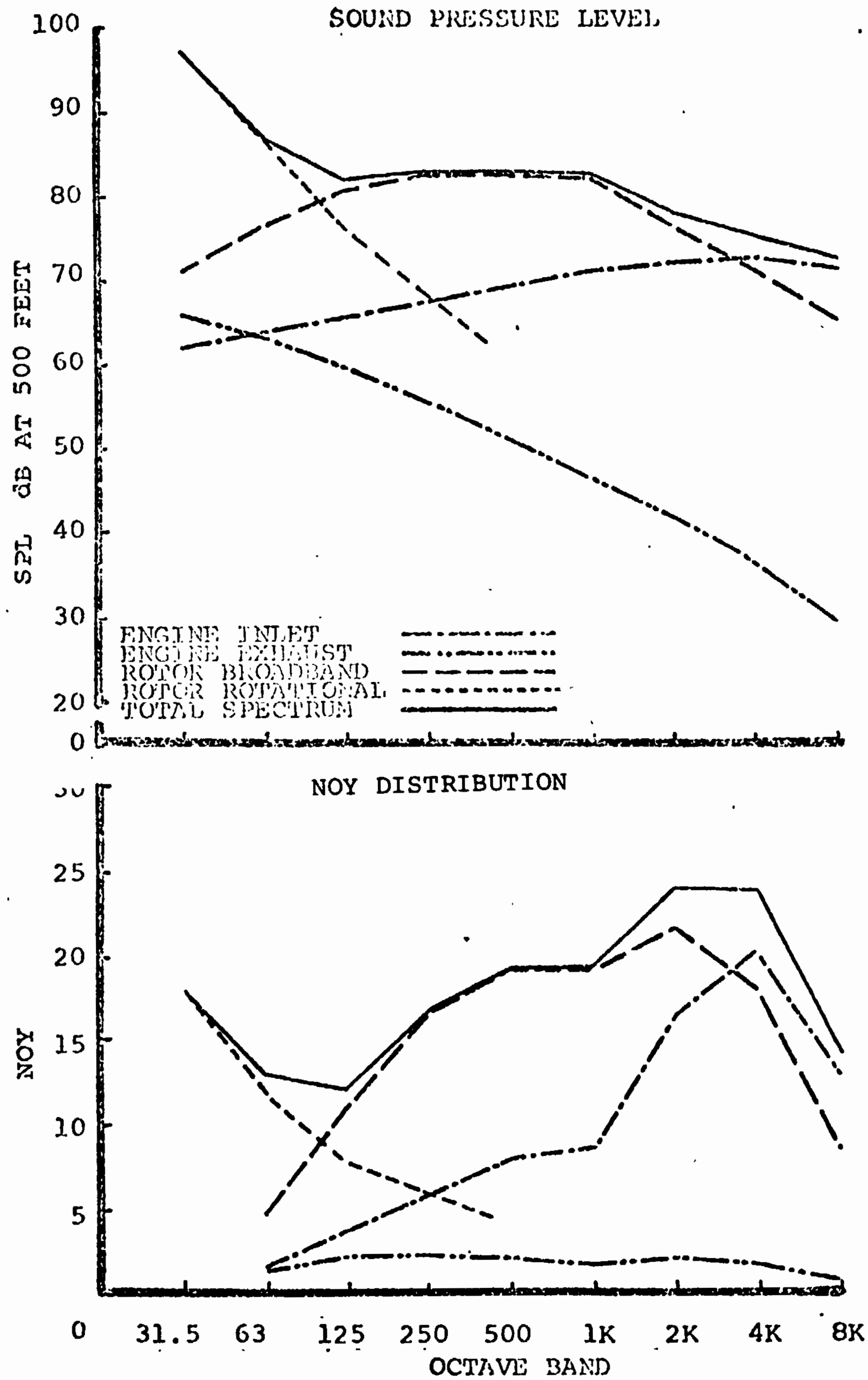
Figure 2.17m. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.



TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 825, W/A = 12.5, PNdB = 100.3

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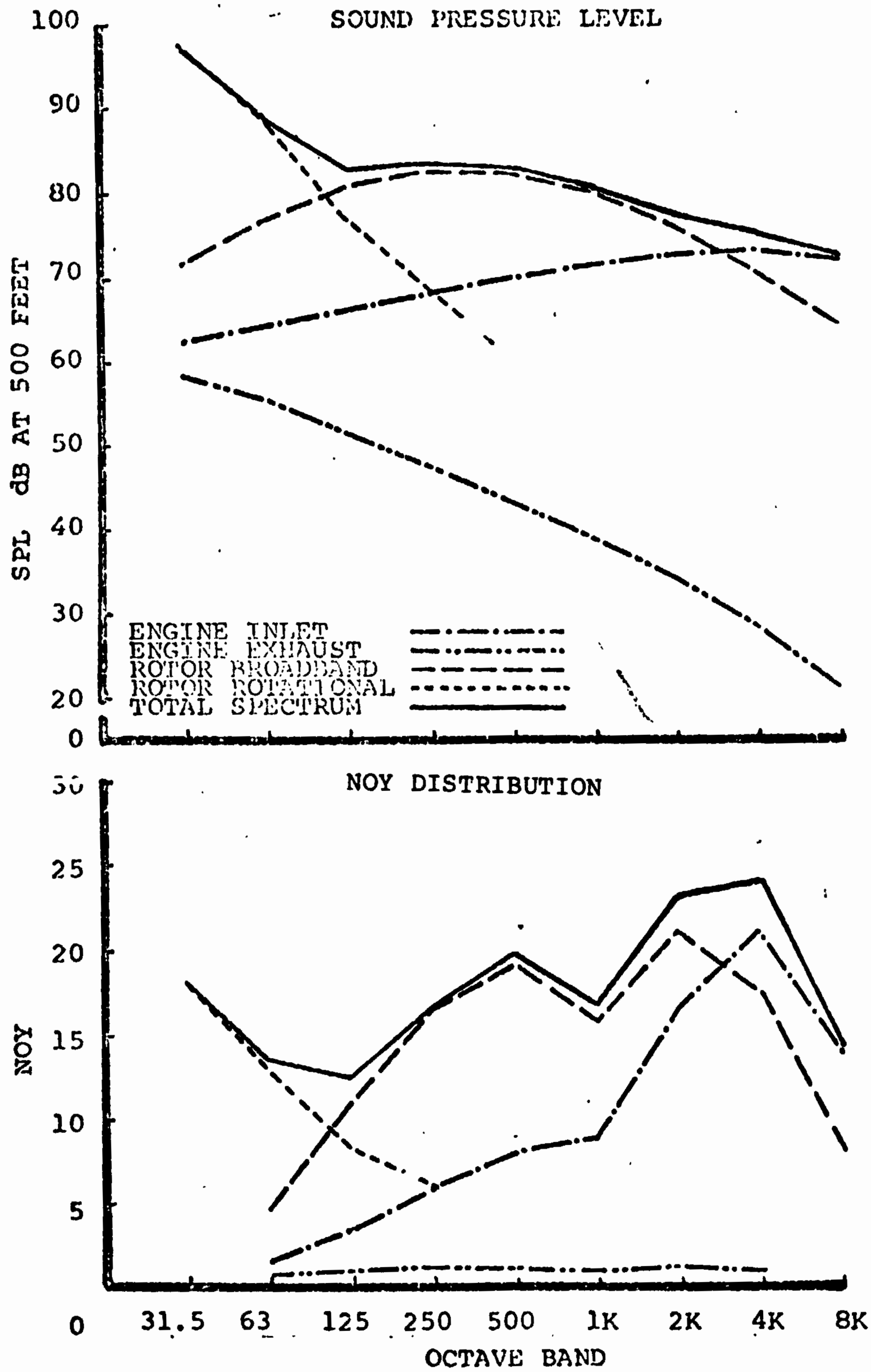
Figure 2.17n. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.



TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 825, W/A = 15, PNdB = 100.2

Figure 2.17o. Tilt Rotor Disc Loading and Tipspeed Trade. 100 Passengers. Altitude = 14,000 Feet.

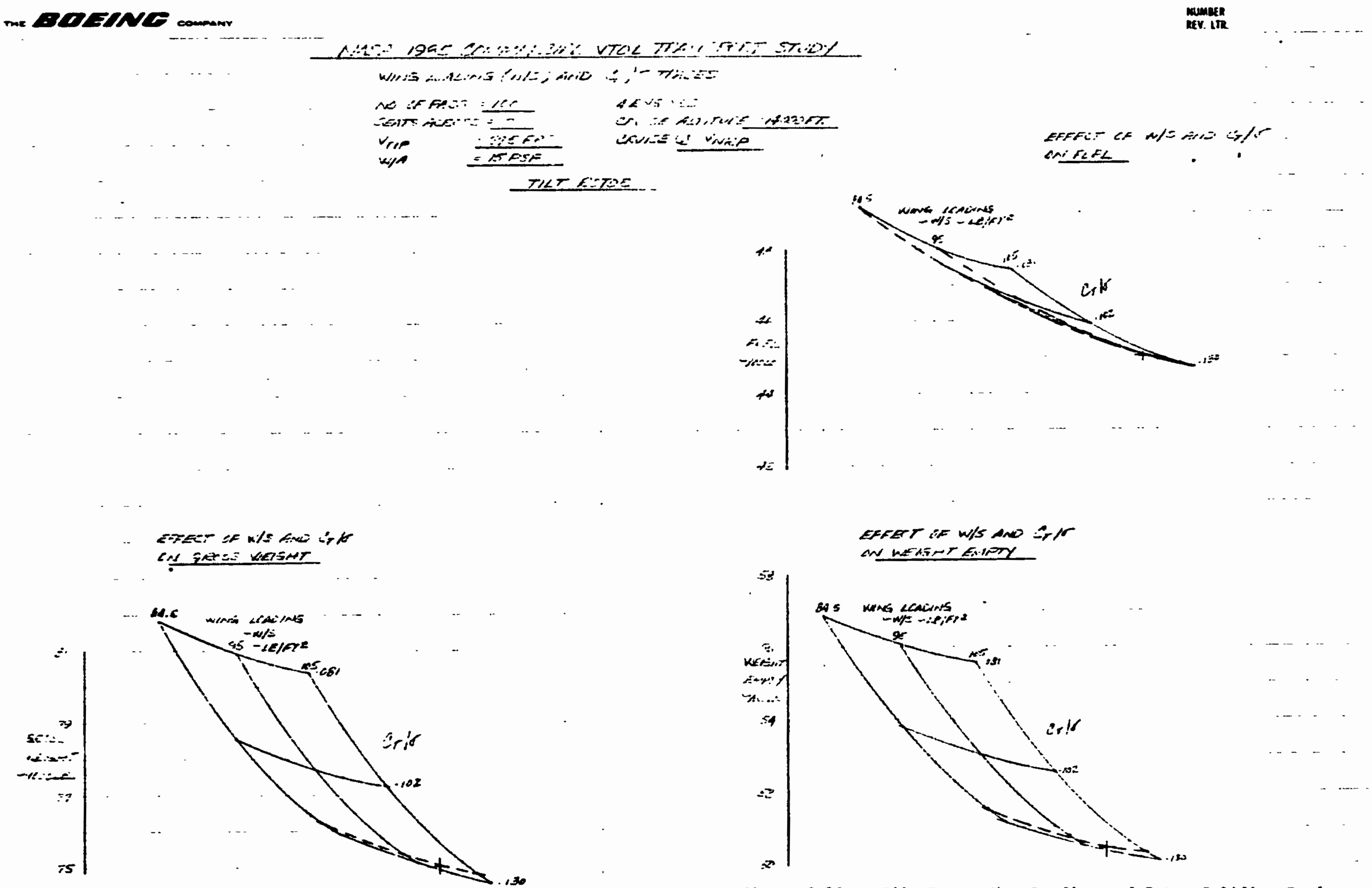


Figure 2.18a. Tilt Rotor Wing Loading and Rotor Solidity Trade. 100 Passengers. Altitude = 14,000 Feet. Hover Tipspeed = 775. Disc Loading = 15 PSF.

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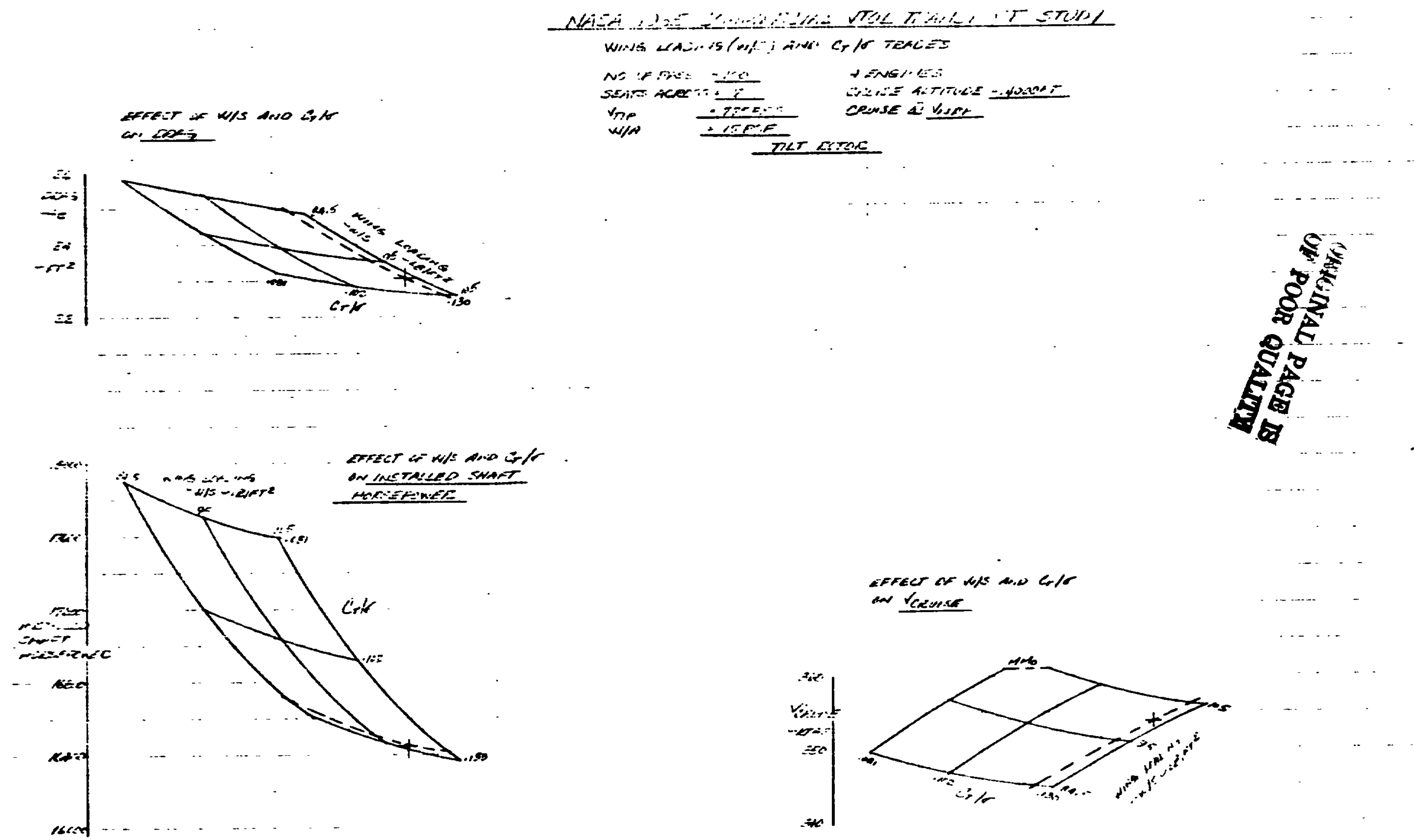

Figure 2.18b. Tilt Rotor Wing Loading and Rotor Solidity Trade. 100 Passengers. Altitude = 14,000 Feet. Hover Tipspeed = 775. Disc Loading = 15 PSF.

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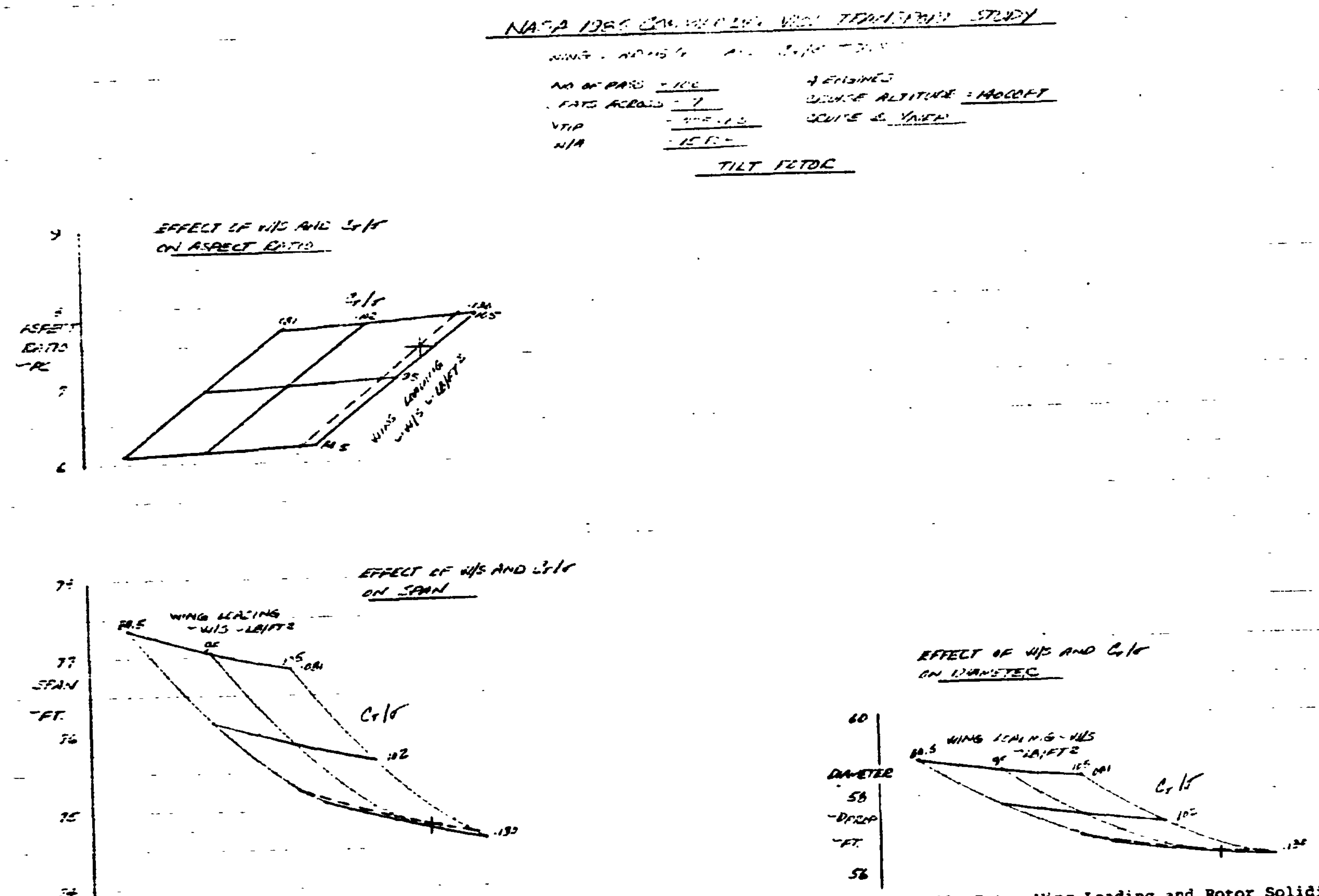


Figure 2.18c. Tilt Rotor Wing Loading and Rotor Solidity Trade. 100 Passengers. Altitude = 14,000 Feet. Hover Tipspeed = 775. Disc Loading = 15 PSF.

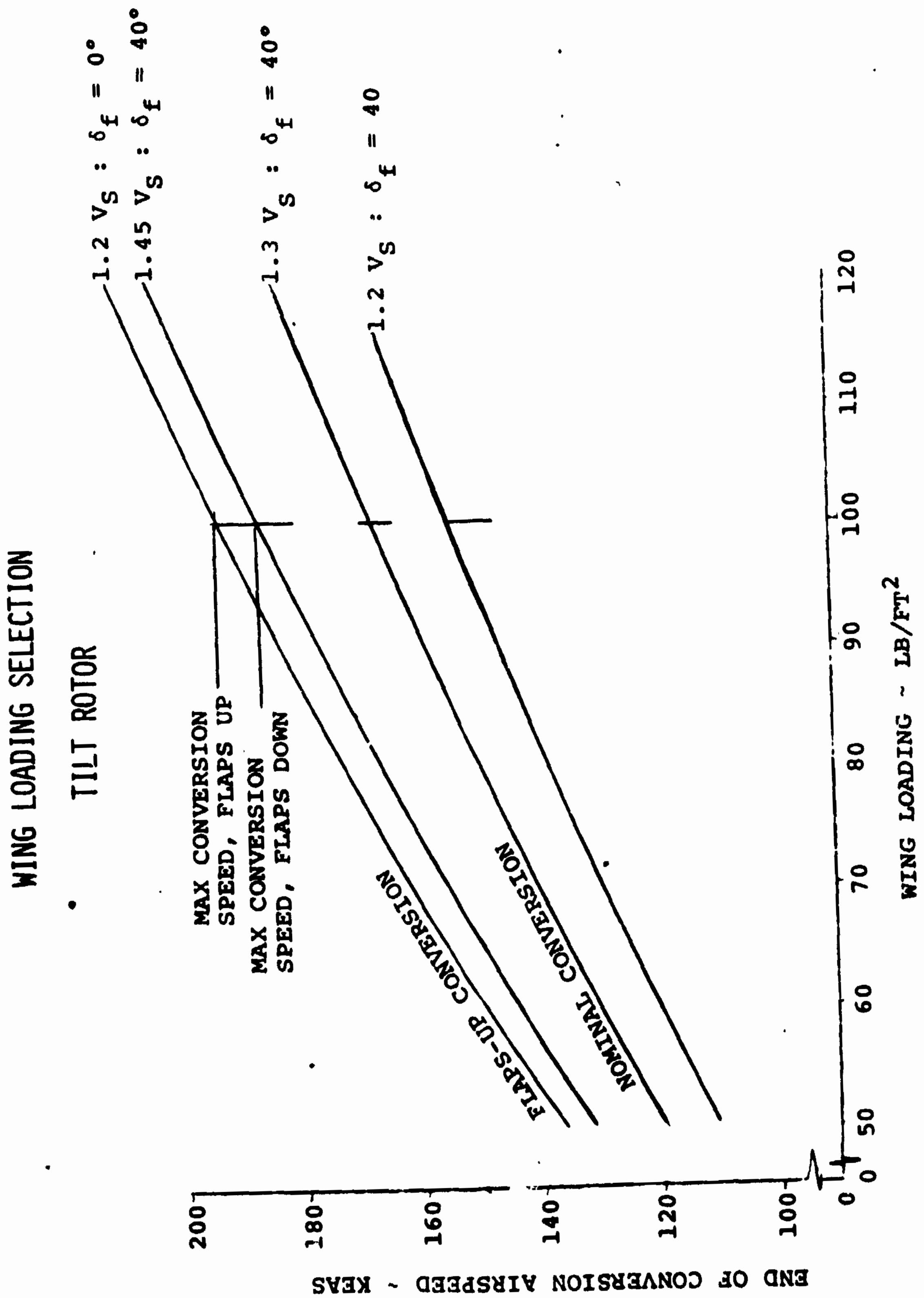
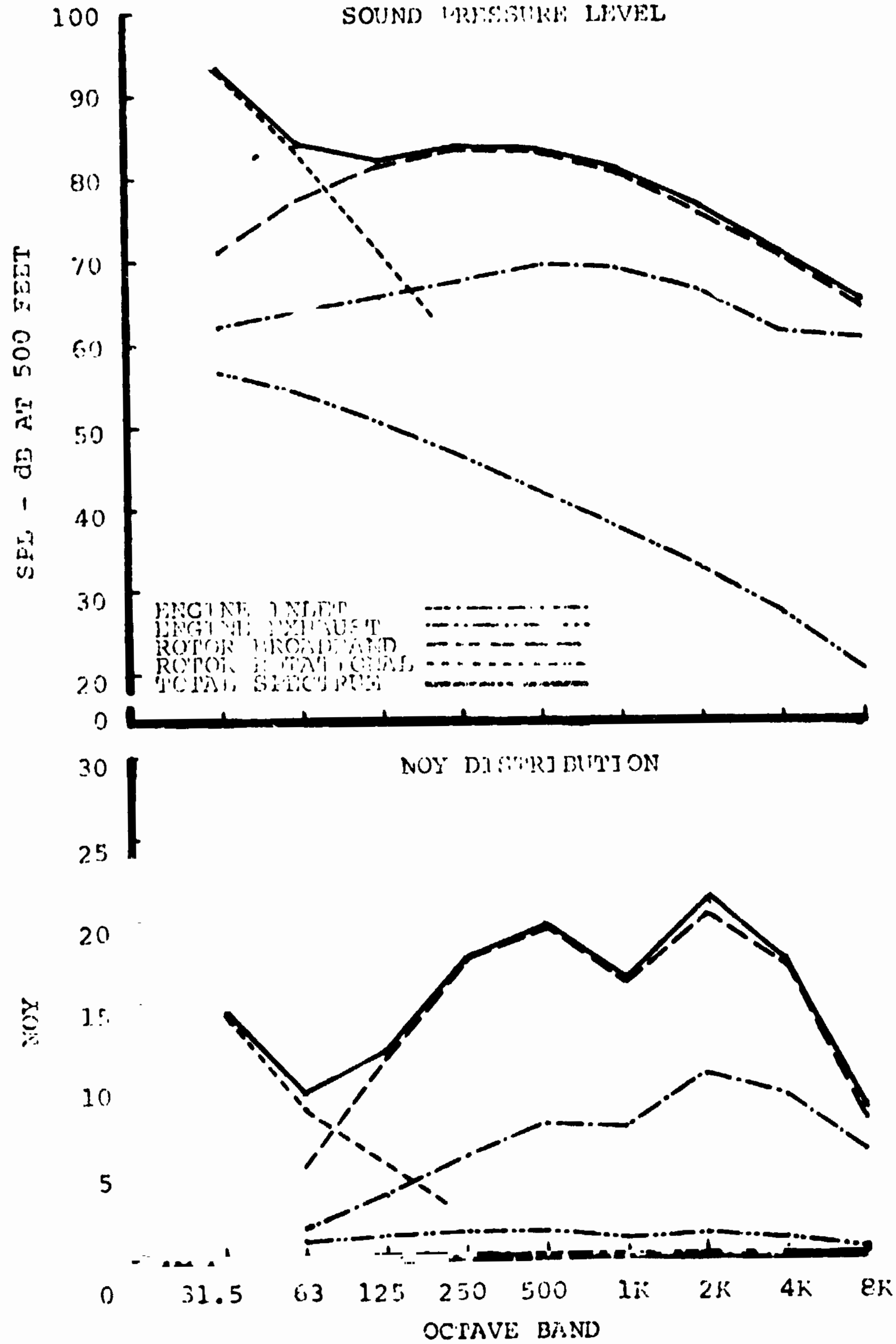


Figure 2.18d. Tilt Rotor Wing Loading and Rotor Solidity Trade. 100 Passengers. Altitude = 14,000 Feet. Hover Tipspeed = 775. Disc Loading = 15 PSF.



TILT ROTOR BASELINE HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 775, CASE = BASELINE, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 98.2

Figure 2.18e. Tilt Rotor Wing Loading and Rotor Solidity Trade. 100 Passengers. Altitude = 14,000 Feet. Hover Tipspeed = 775. Disc Loading = 15 PSF.

2.4 TREND DATA FOR NOISE DERIVATIVE - TILT ROTOR AIRCRAFT DESIGNS

The second objective of the design study was to determine the effect of external noise design criteria on the design of the tilt rotor aircraft. The approach used to achieve this objective was to size two additional aircraft; one 5 PNdB more noisy and one 5 PNdB less noisy than the baseline tilt rotor design.

The noise component which predominates in the design point aircraft sound pressure level spectrum is the rotor broadband noise. This results is in part due to the engine inlet attenuation treatment used. The parameters available to the designer to achieve different noise levels are essentially tipspeed, blade loading, since disc loading is not a powerful noise parameter in the range under consideration.

The noise derivative aircraft trend study was made by taking perturbations in rotor tipspeed and solidity about the design point aircraft. The results of these trend studies are shown in Figures 2.19a to 2.19v. The direct operating cost data are superimposed on the gross weight carpet plot in Figure 2.19a. Three lines of constant 500-foot sideline perceived noise level are also shown. The line labelled Δ0 PNdB is a family of aircraft whose hover noise level are the same as the baseline aircraft. The baseline vehicle is identified on this plot at the intersection of the 0 PNdB line and a solidity of 0.09.

The line labelled Δ -5 PNdB is a similar family of aircraft whose 500-foot sideline perceived noise level is 5 PNdB less noisy than the baseline aircraft. By examination of this line in relation to the lines of constant direct operating cost, a minimum direct operating cost vehicle 5 PNdB less noisy than the baseline can be selected. The -5 PNdB aircraft has a tipspeed of 640 feet per second and a rotor solidity of 0.1115. It is interesting to note that this aircraft has more solidity than the minimum required and results in a gross weight of 79,682 pounds.

The line labelled delta +5 PNdB constitutes a third family of aircraft whose 500-foot sideline perceived noise level is 5 PNdB more noisy than the baseline aircraft. This line is almost parallel to the constant tipspeed lines and shows reduced direct operating costs as solidity is reduced. This results in the selection of the aircraft defined by the intersection of the minimum solidity limit and the +5 PNdB line. This point results in a hover tipspeed of 915 feet per second and a solidity of .081. This aircraft has a design gross weight of 73,217 pounds.

The parametric data which relate to the selection chart discussed above are shown in Figures 2.19b to 2.19f.

Figure 2.19b shows the parametric variation of the 500-foot sideline noise level for the matrix of noise derivative aircraft considered. The overall sound pressure level data corresponding to these parametric vehicles are also included

in Figures 2.19g to 2.19t. Figure 2.19u is the -5 PNdB sound pressure level data for the -5 PNdB aircraft. Similar data for the +5 PNdB vehicle is given in Figure 2.19v.

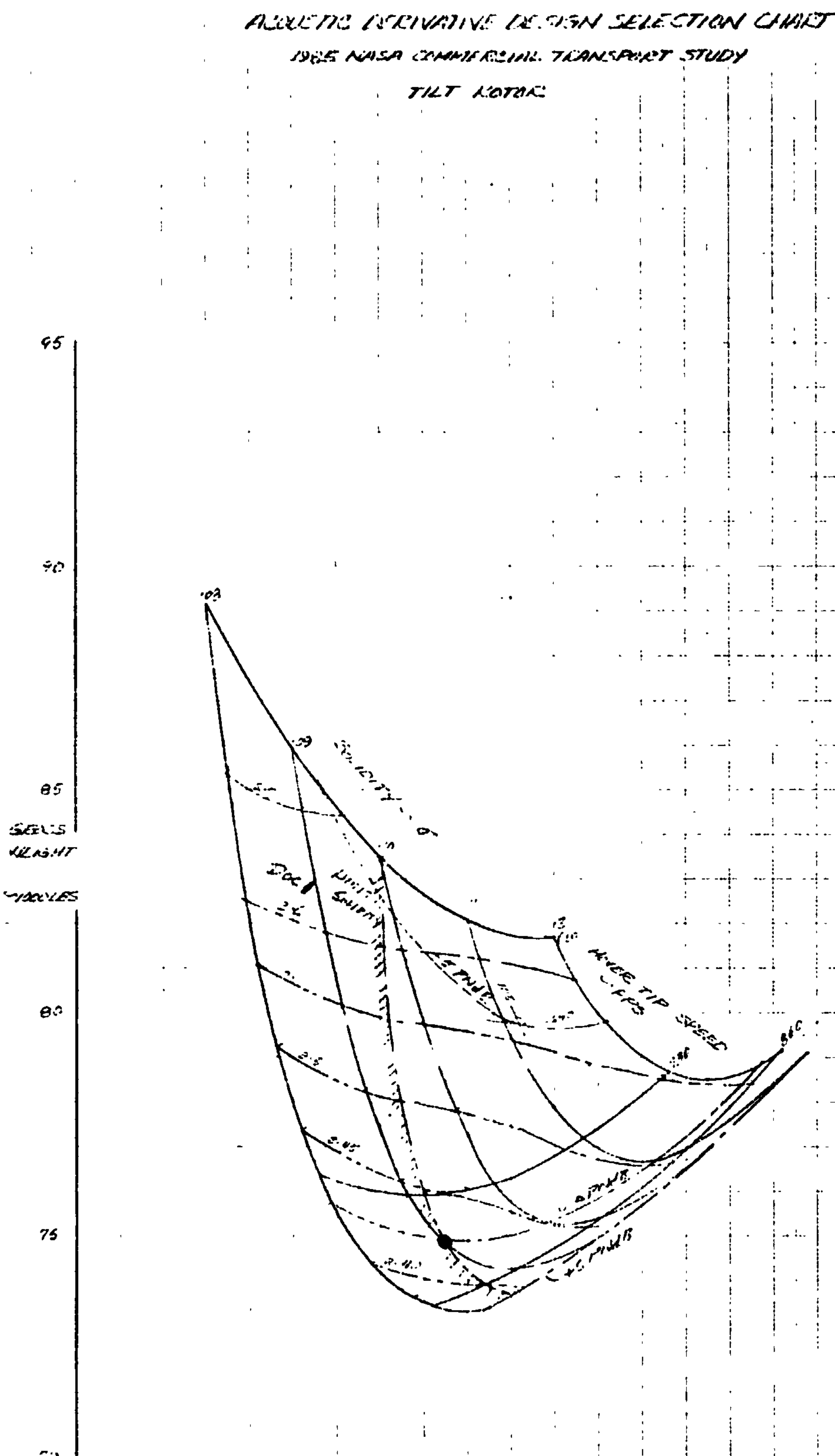


Figure 2.19a. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.

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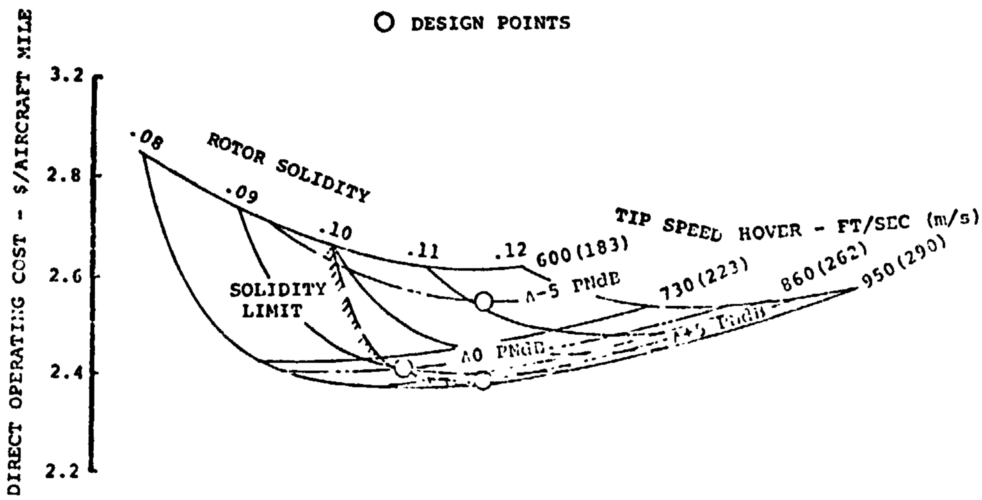
100 PASSENGER - TILT ROTOR



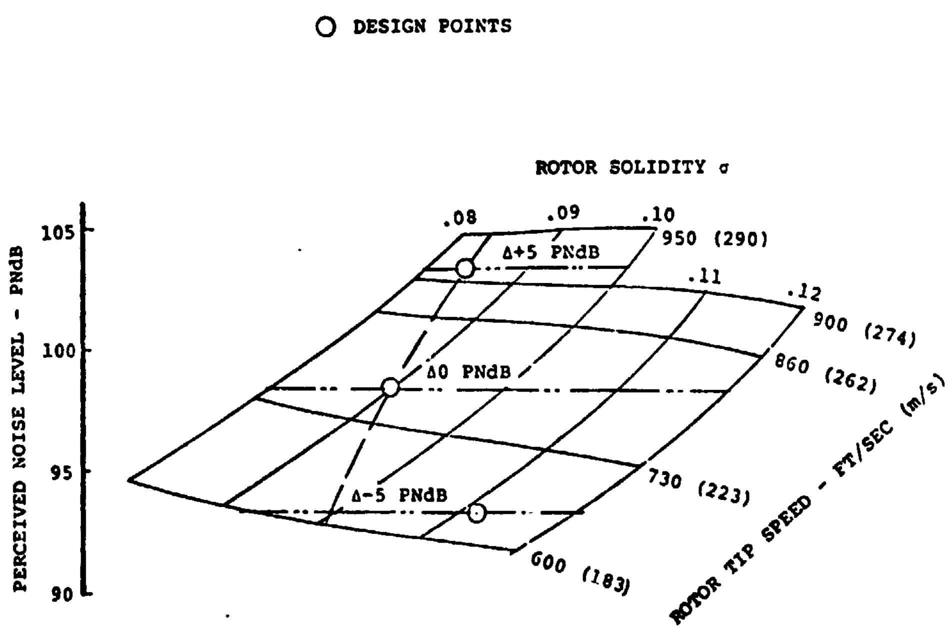


FIGURE 2.19B. TREND DATA FOR NOISE DERIVATIVE TILT ROTORS - 100 PASSENGERS. ALTITUDE = 14,000 FEET, DISC LOADING = 15 PSF - WING LOADING = 100 PSF

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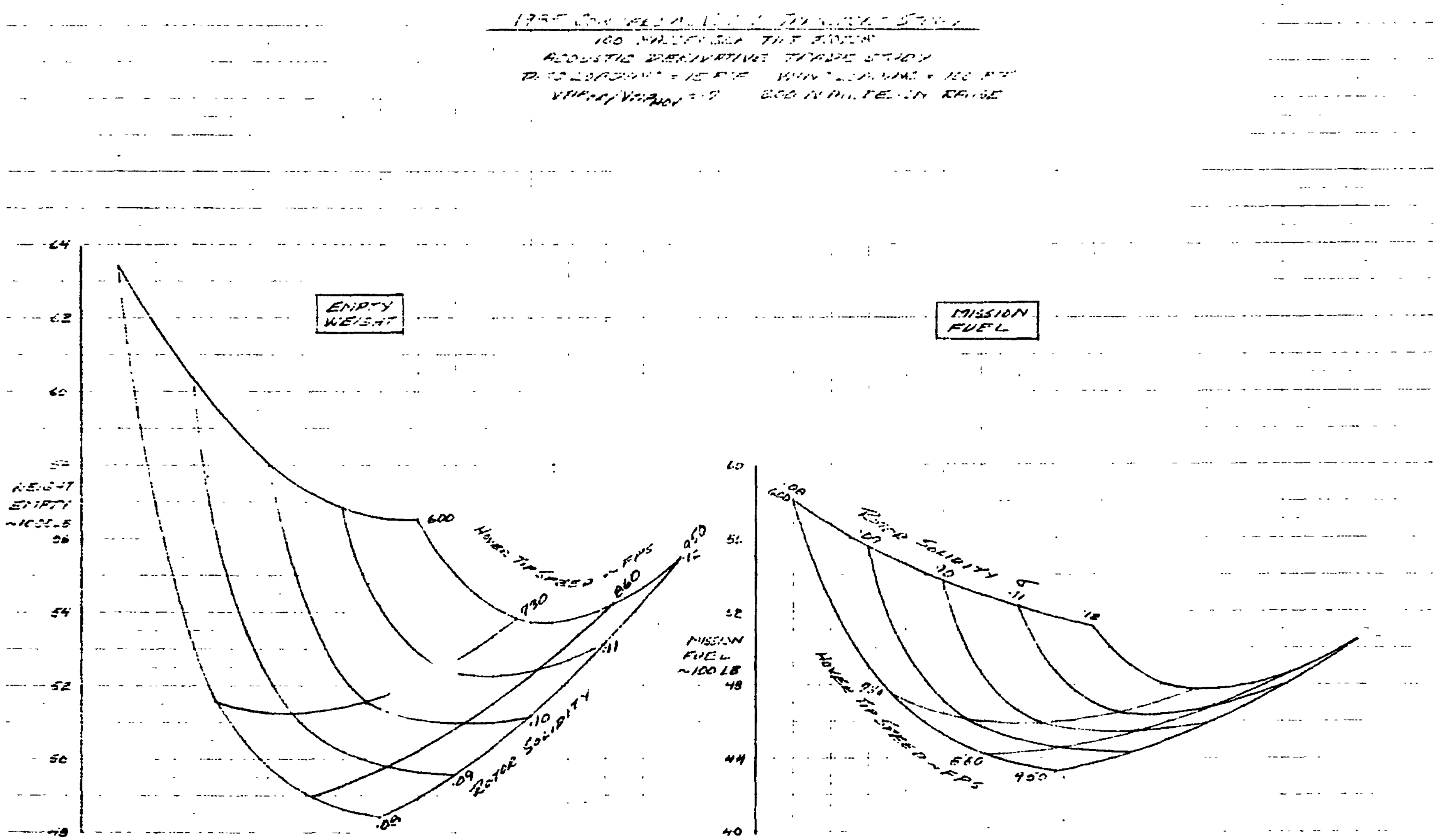

Figure 2.19c. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.

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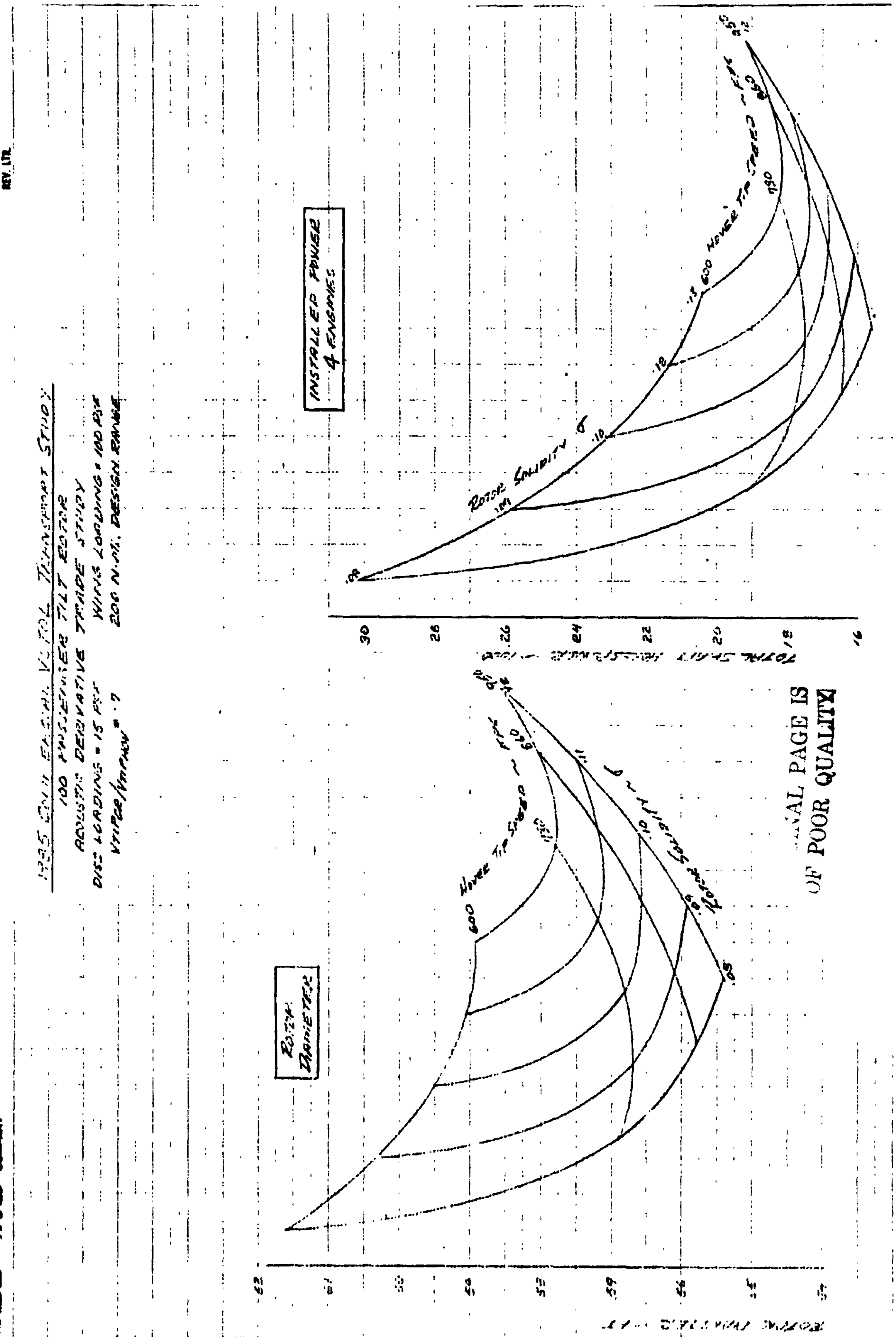

Figure 2.19d. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.

100 PASSENGER TILT ROTOR
ACOUSTIC DERIVATIVE TRADE STUDY
VTIP CR / VTIP HOV = .7   200 N.MI. DESIGN RANGE

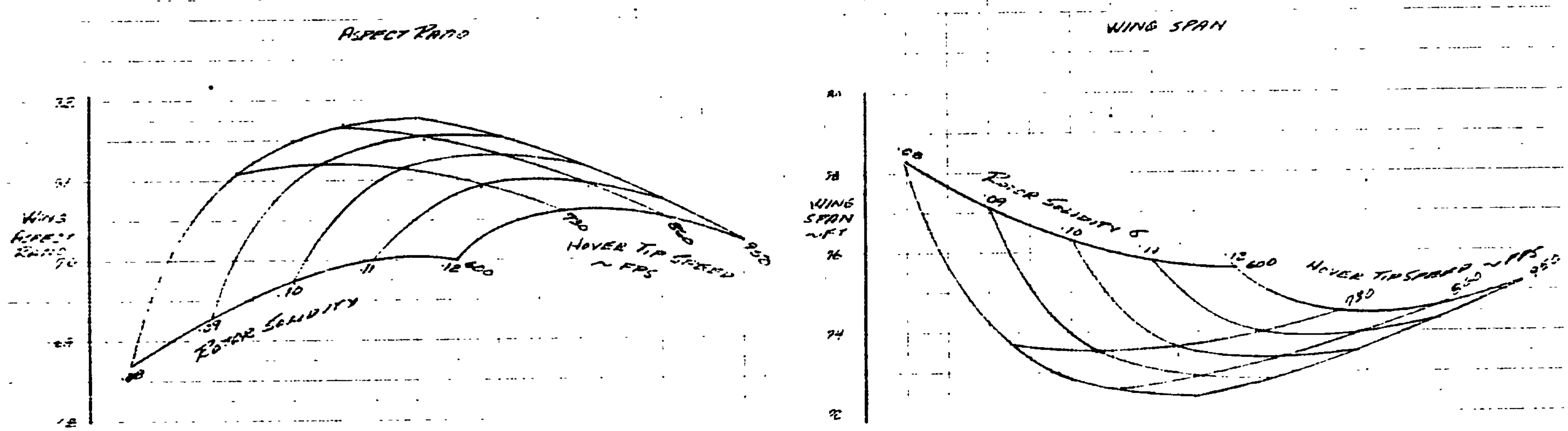

Figure 2.19e. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.

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ACOUSTIC DERIVATIVE TRADE STUDY

WING LOADING = 100 PSF

DESIGN RANGE

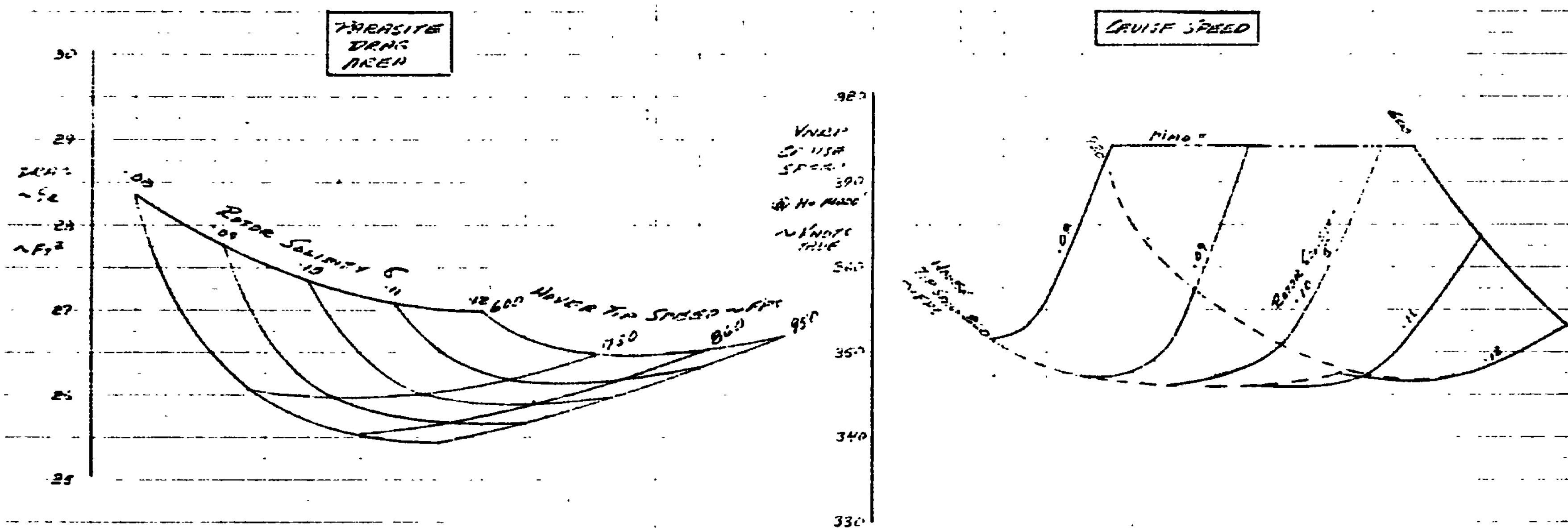

Figure 2.19f. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.

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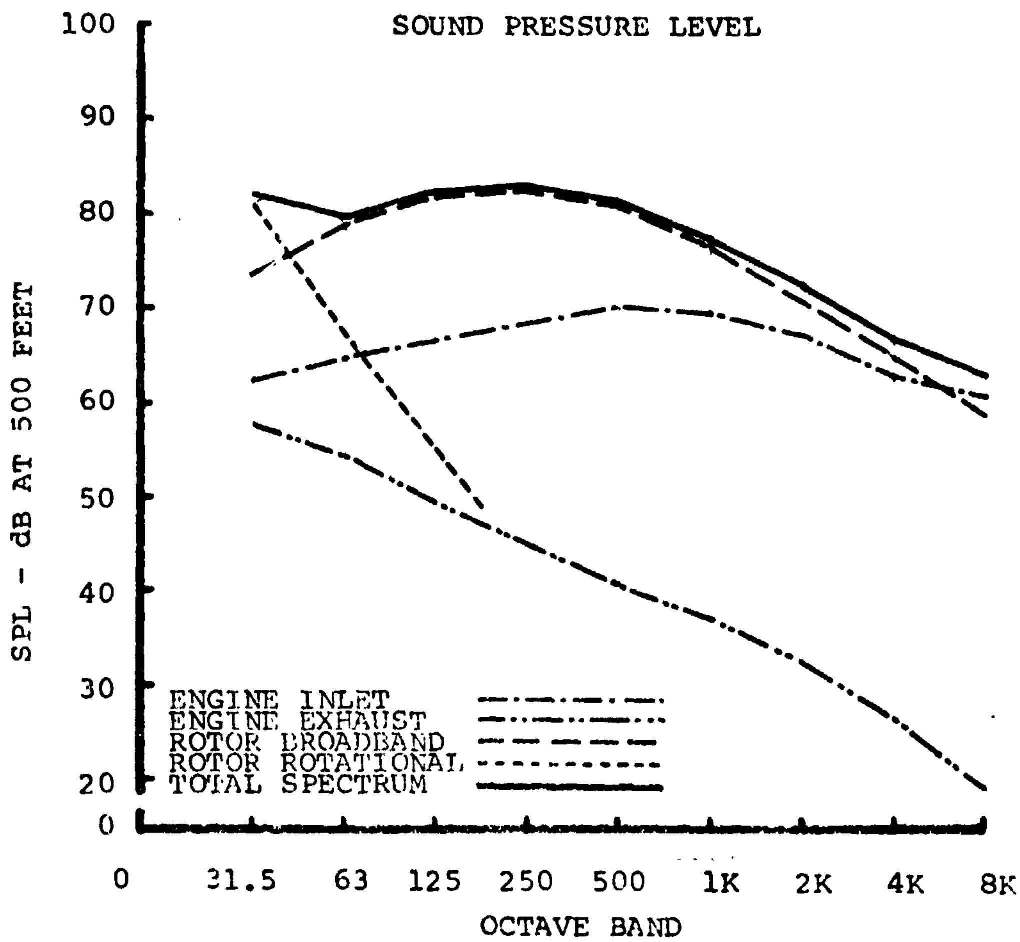
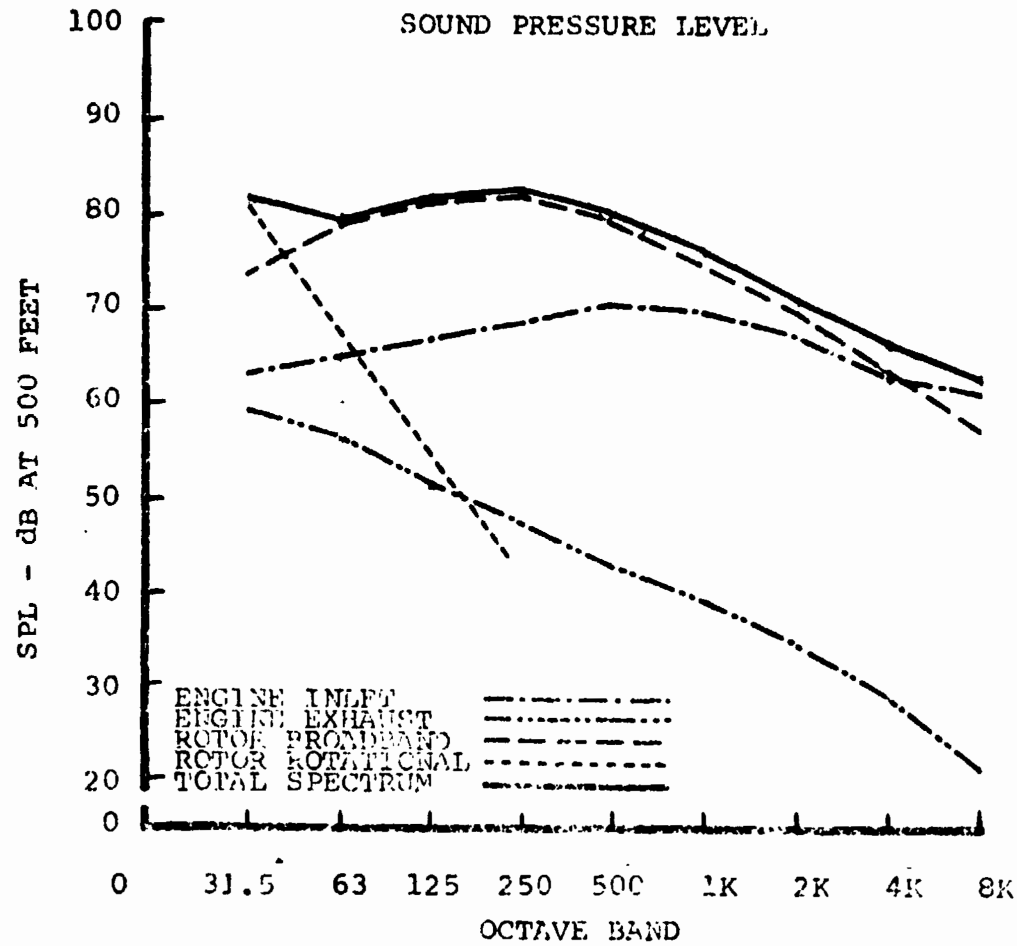


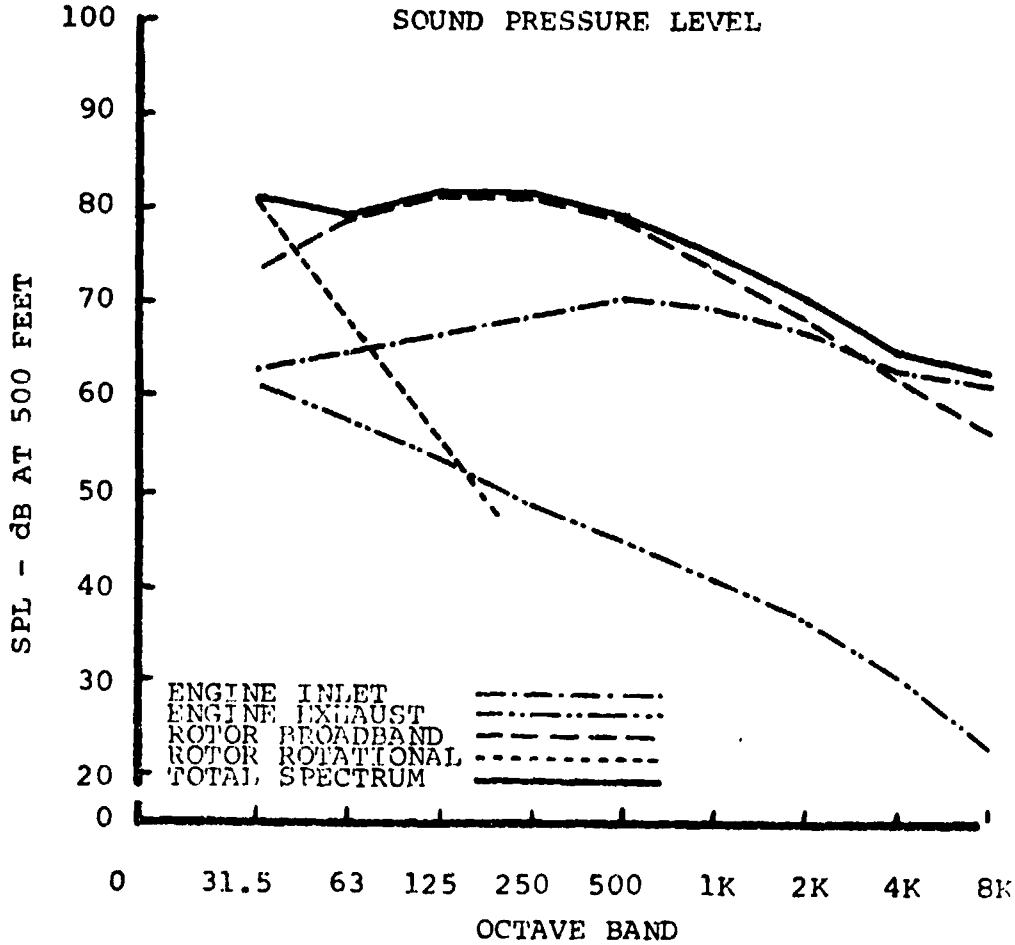
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .08, CASE = 1, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 94.9

Figure 2.19g. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



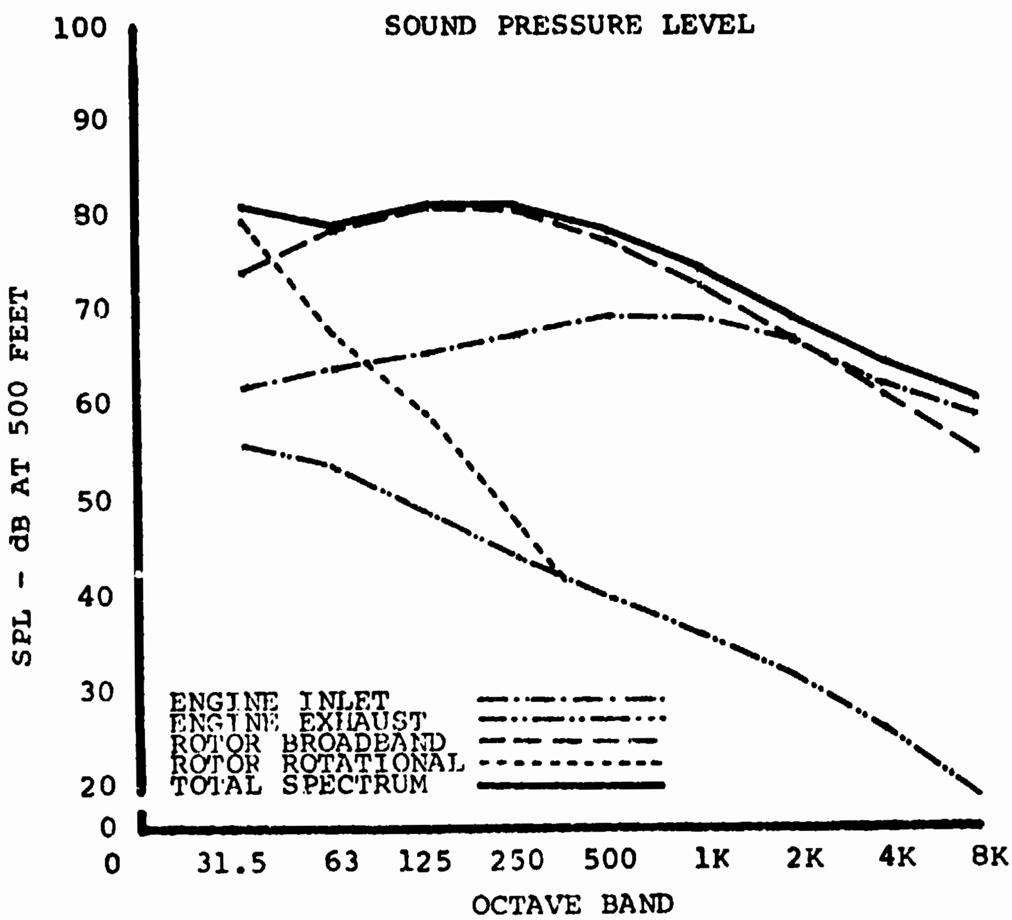
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .09, CASE = 2, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 94.0

Figure 2.19h. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



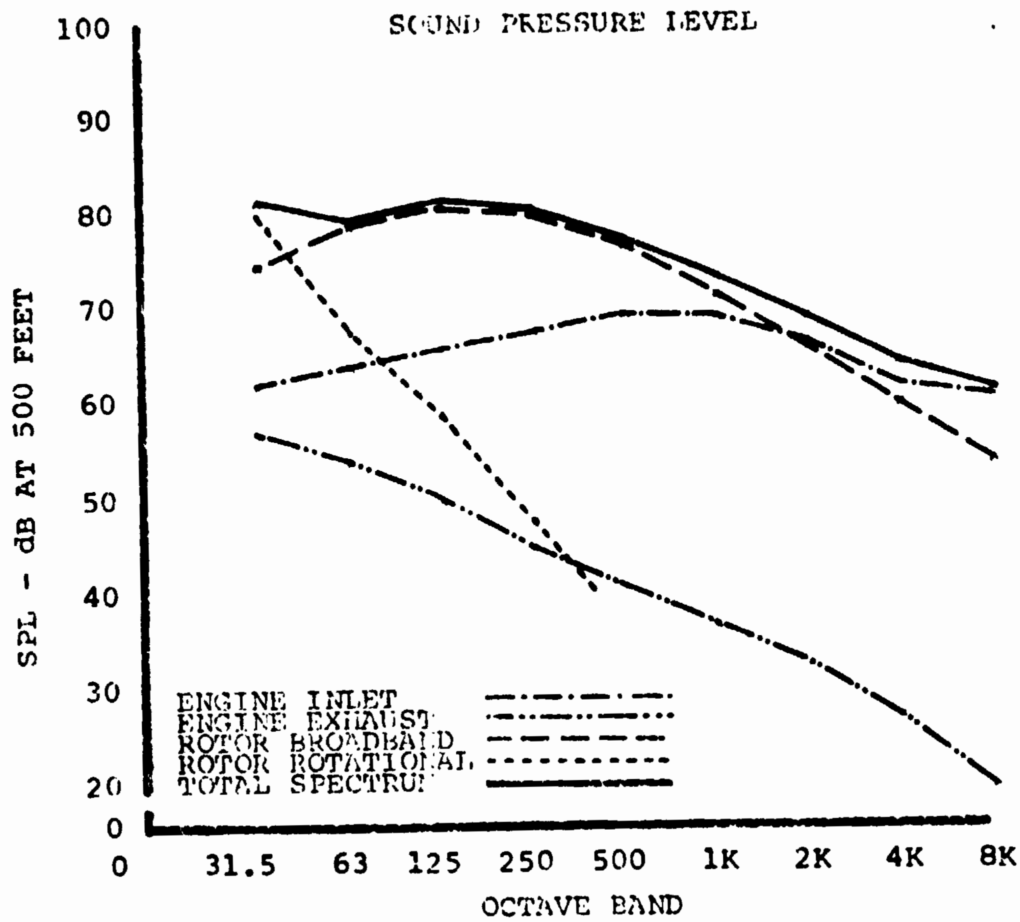
TILT ROTOR HOVER NOISE PSECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 600, SIGMA = .1, CASE = 3, WORST
AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER,
PNdB = 93.3

Figure 2.19i. Trend Data for Noise Derivative Tilt Rotors.
100 Passengers. Altitude = 14,000 Feet.
Disc Loading = 15 PSF. Wing Loading = 100 PSF.



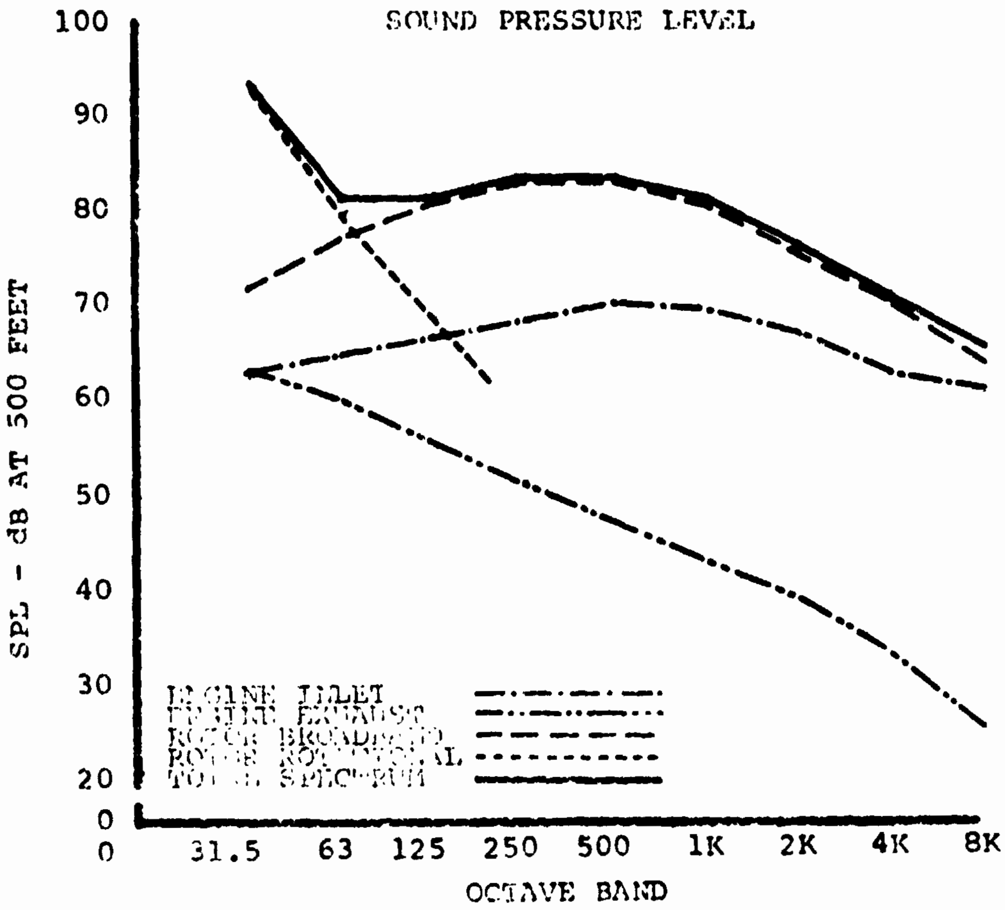
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 600, SIGMA = .11, CASE = 10,
WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM
OBSERVER, PNdB = 92.5

Figure 2.19j. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



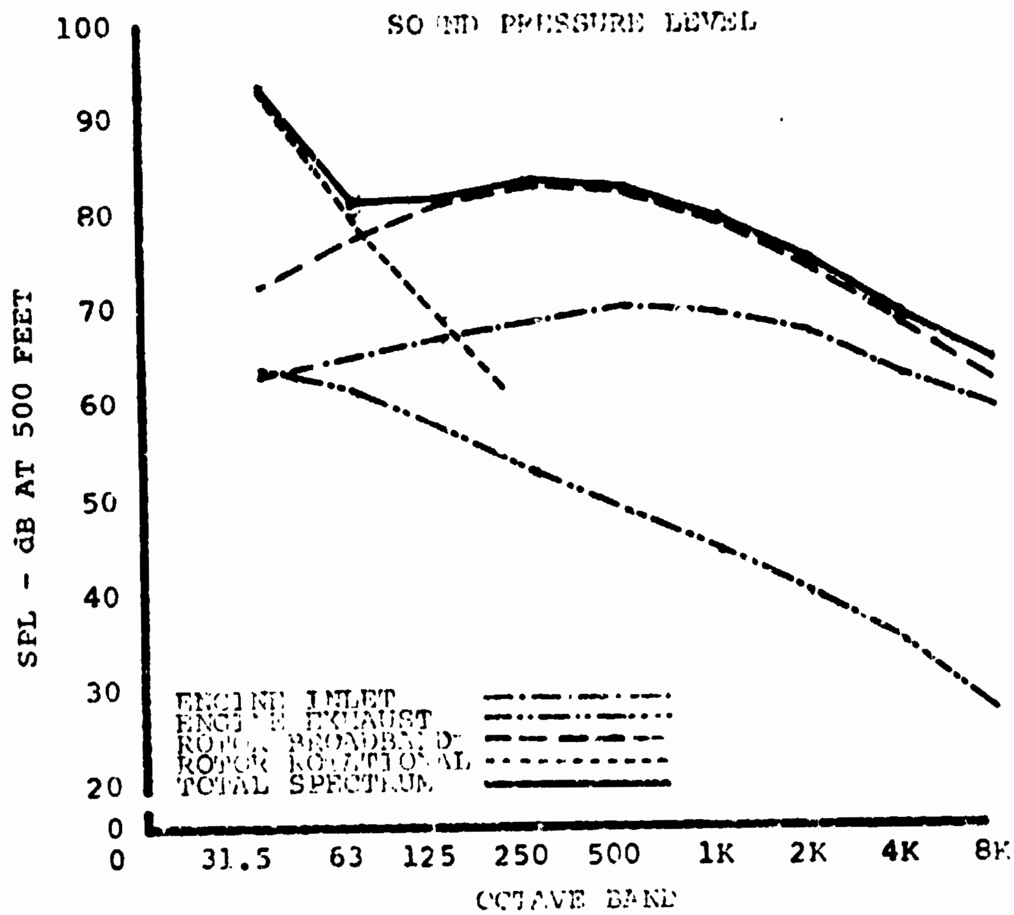
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 600, SIGMA = .12, CASE = 11, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 92.1

Figure 2.19k. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



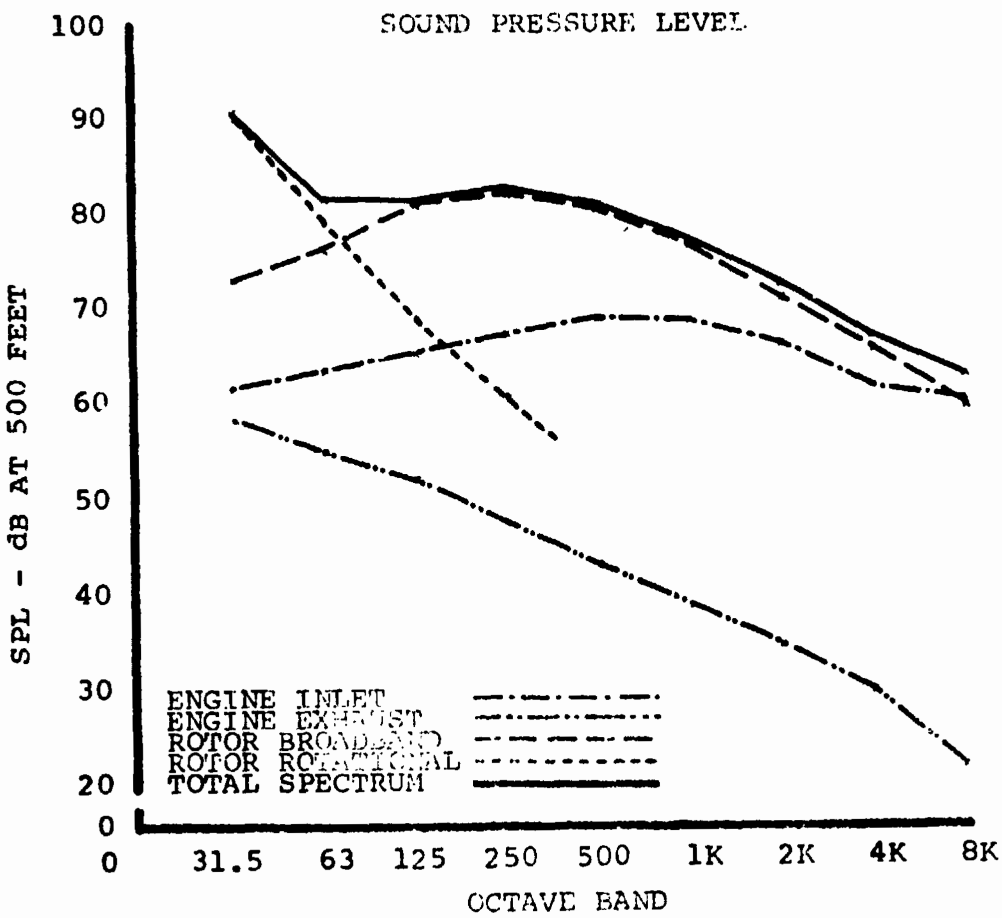
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 730, SIGMA = .08, CASE = 4, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 98.1

Figure 2.191. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



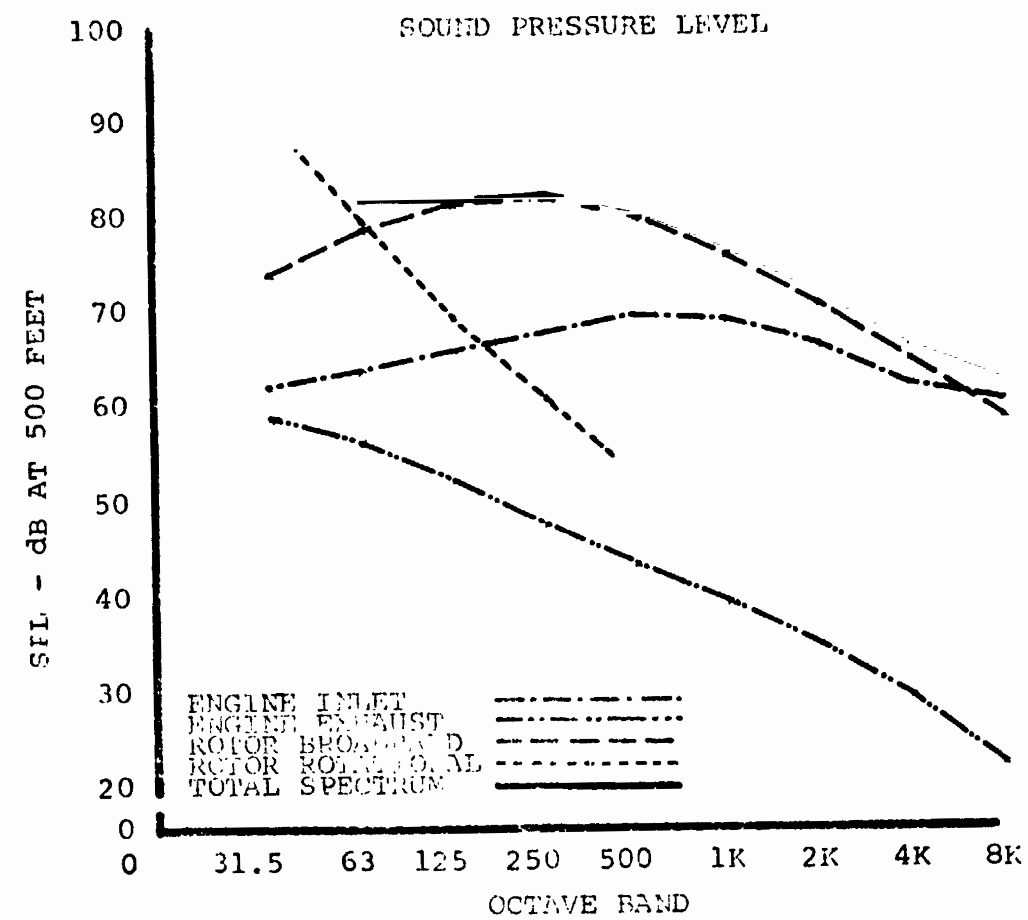
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 730, SIGMA = .09, CASE = 5, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 97.3

Figure 2.19m. **Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.**



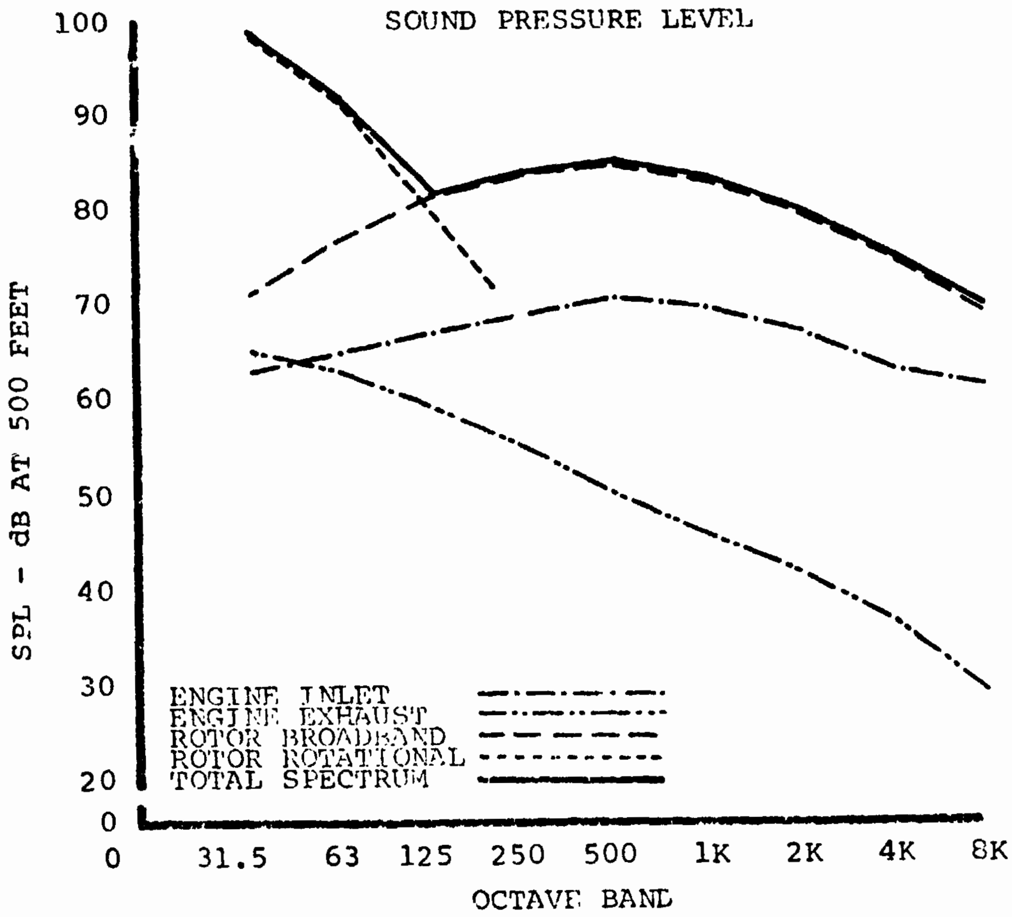
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 730, SIGMA = .11, CASE = 12, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 95.5

Figure 2.19m. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 1[illegible].000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



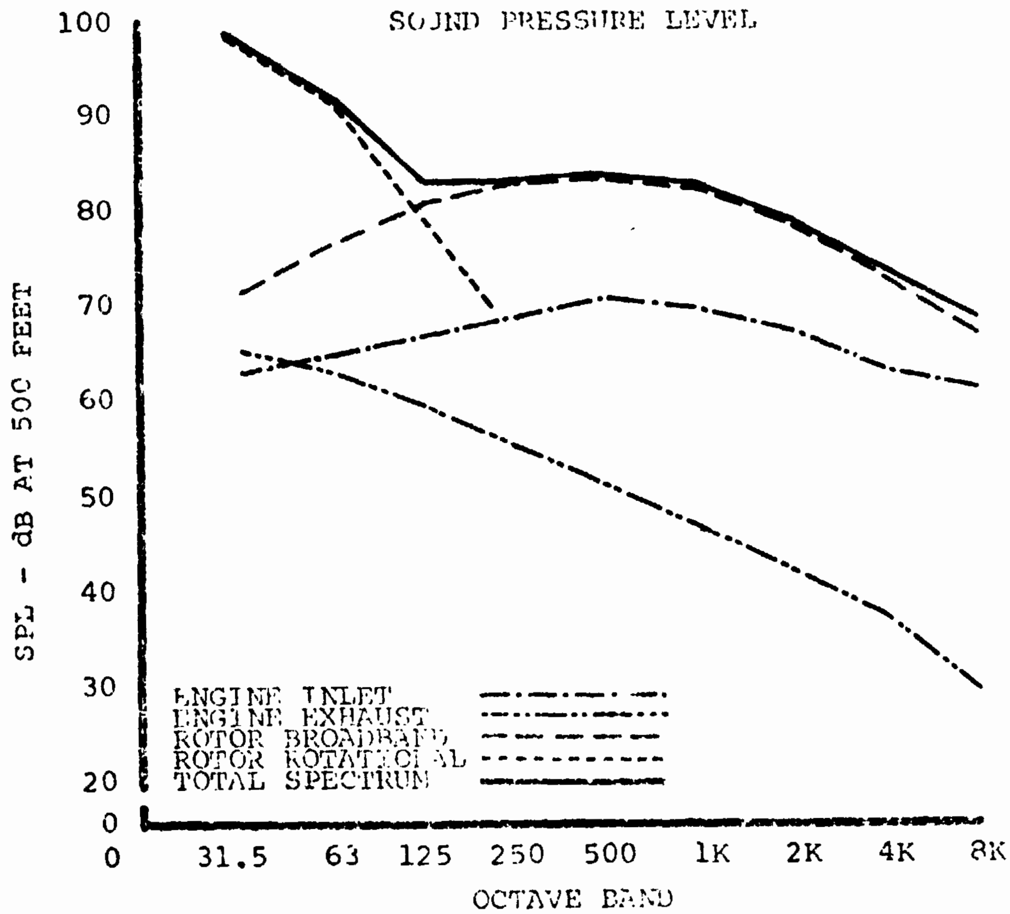
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 730, SIGMA = .12, CASE = 13, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 95.1

Figure 2.19o. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



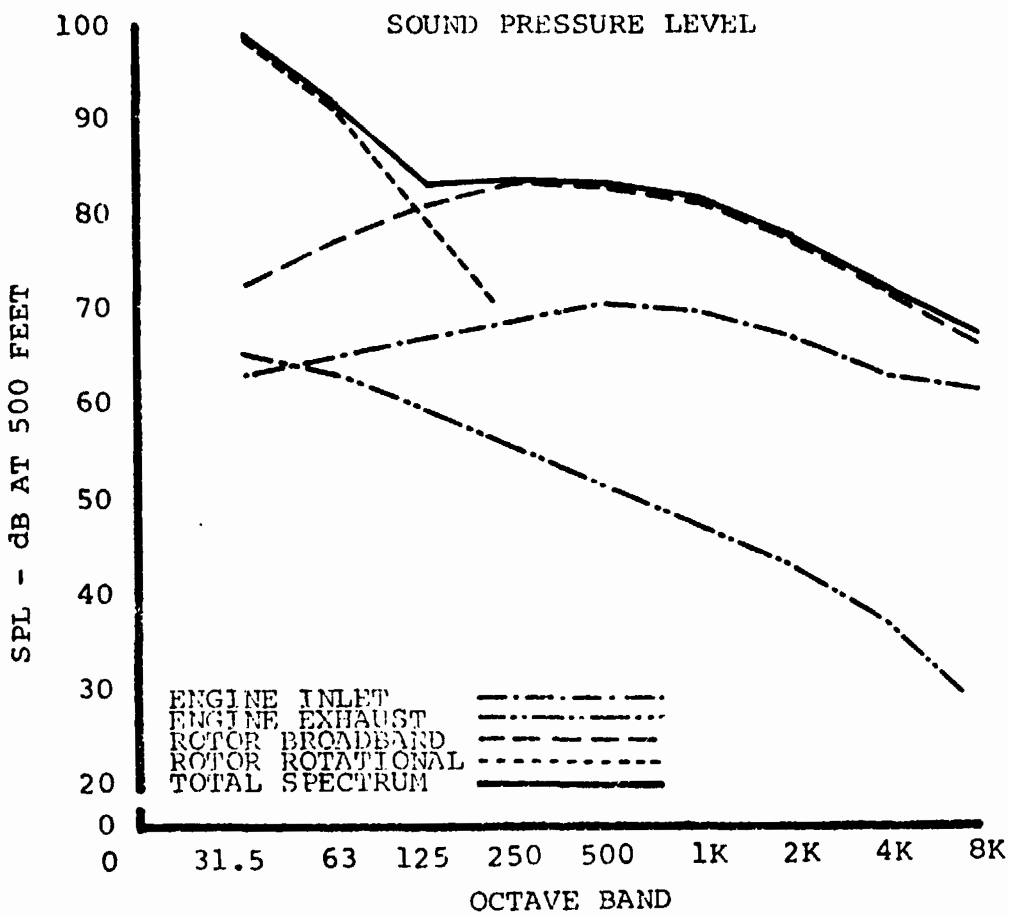
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION,
100 PASSENGERS, VT = 860, SIGMA = .08, CASE = 7, WORST
AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER,
PNdB = 102.0

Figure 219p. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



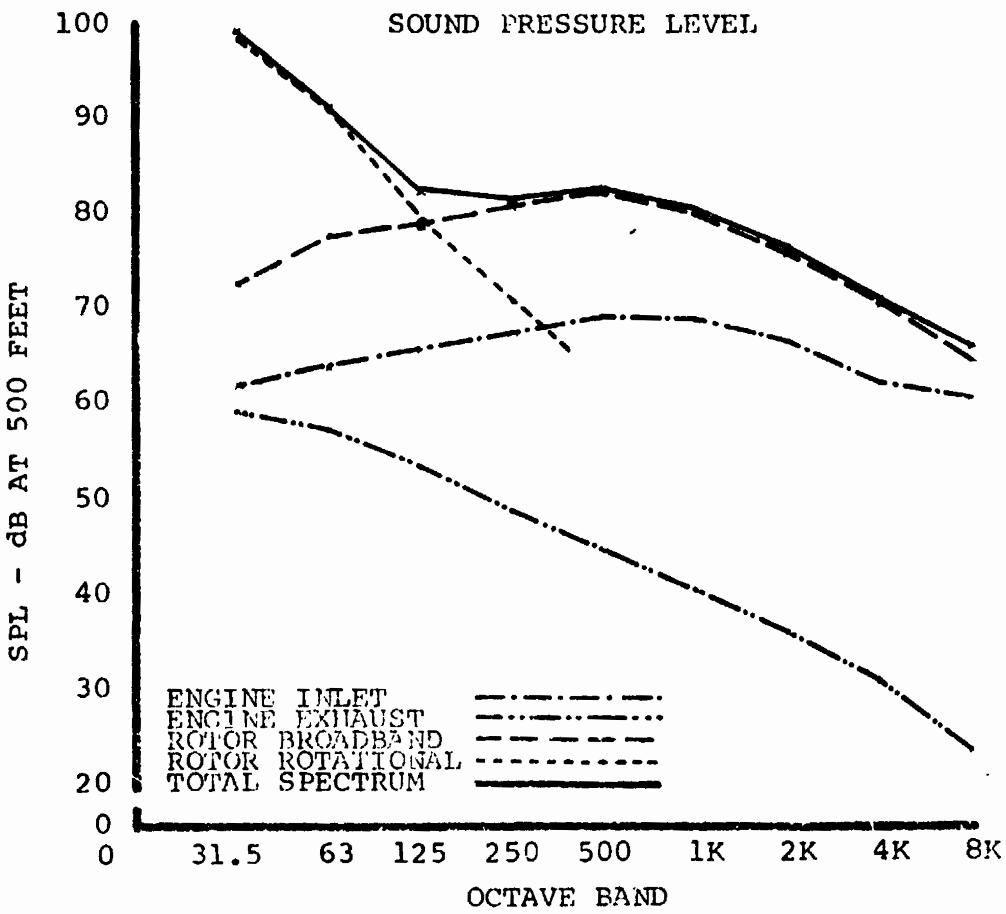
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 860, SIGMA = .09, CASE = 8, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 101.0

Figure 2.19q. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



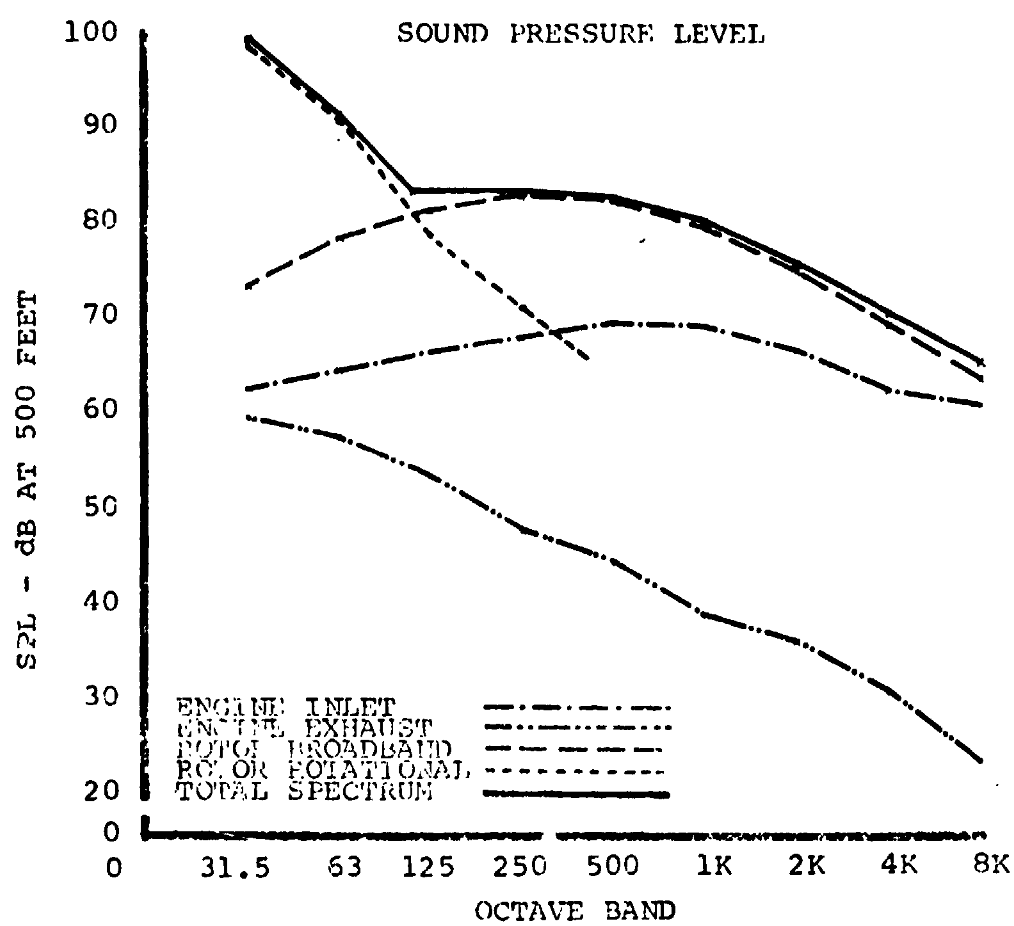
TILT ROTOR HOVER NOISE PSECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 860, SIGMA = .10, CASE = 9, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 99.8

Figure 2.19r. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



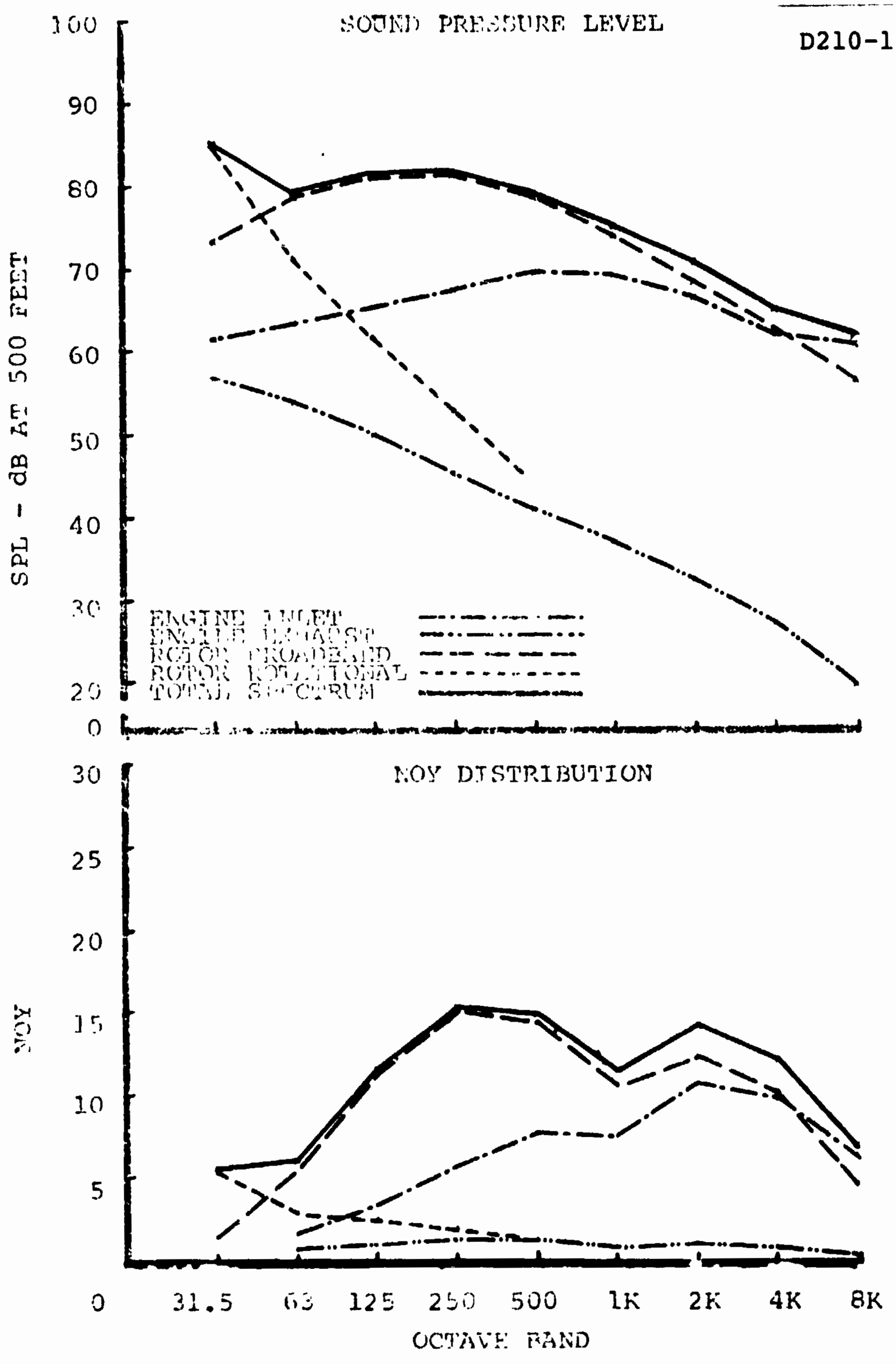
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 860, SIGMA = .11, CASE = 14, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 99.4

Figure 2.19s. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



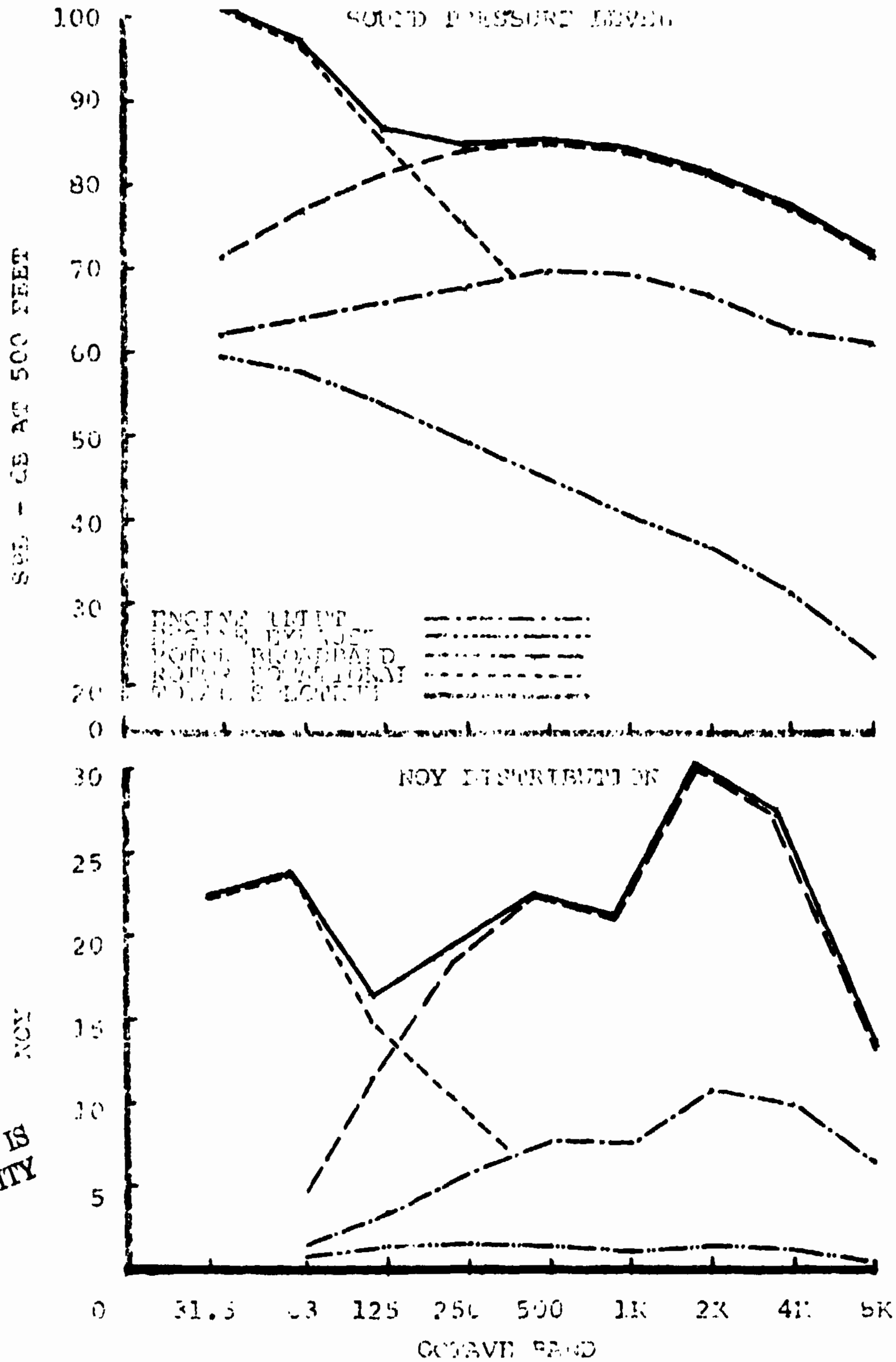
TILT ROTOR HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 860, SIGMA = .12, CASE = 15, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 99.1

Figure 2.19t. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



TILT ROTOR D.P., -5 PNdB HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 640, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 93.3

Figure 2.19u. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.



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TILT ROTOR D.P., +5 PNdB HOVER NOISE SPECTRUM AND NOY DISTRIBUTION, 100 PASSENGERS, VT = 915, SIGMA = .081, WORST AZIMUTH, AIRCRAFT 100' ABOVE AND 500' AWAY FROM OBSERVER, PNdB = 102.

Figure 2.19v. Trend Data for Noise Derivative Tilt Rotors. 100 Passengers. Altitude = 14,000 Feet. Disc Loading = 15 PSF. Wing Loading = 100 PSF.

3.0 DESIGN DATA AND METHODS

This section of the report contains detailed data in each of the technology disciplines to provide background for the design study results given in Volume I.

3.1 AERODYNAMICS AND PERFORMANCE

Tandem Helicopters

The mission performance and aircraft sizing calculations have been performed using an automated method called HESCOMP. This computer program was developed for NASA by the Boeing Vertol Company under Contract NAS2-6107. The method is an iterative procedure which takes an initial aircraft size and flies the mission to determine mission fuel. The mission fuel weight is checked against the weight allowance in the aircraft, and the aircraft is then resized and reflown until the vehicle size is compatible with the mission requirements. A detailed description of this method can be found in the HESCOMP manual, Reference 2.

The mission performance data shown in Volume I for each of the three tandem helicopters is a summary of the detailed mission analysis data resulting from HESCOMP computer output. The detailed mission data are included here in Tables 3.1 to 3.3 for the baseline tandem helicopter and the ±5 PNdB noise derivative tandem helicopters.

Hover Download - Tandem Helicopters

The airframe download for the tandem helicopter was estimated using a semi-empirical analysis. This analysis divides the

NASA HELO VTIP=725 W/A=9 D/L/D=0   NOP=100 H=5000   ITERATION 2A   PAGE 7

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H E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM   B-91

MISSION PERFORMANCE DATA

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PERF	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PERF	AUX. ENG. FUEL FLOW (LBS/HR)
0.0	0.0	0.0	67175.	0.	0.0	1725.0	T	0.0	739.	----	----	----	
0.017	0.0	12.3	67163.	0.	0.0	1725.0	T	0.0	739.	----	----	----	

TAKEOFF, HOVER, OR LAND AT T/W = 1.140 FOR 0.033 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PERF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELDCM	FMI	CPPRO	CPIND	CDO
0.017	0.0	12.3	67163.	0.	0.0	2456.7	P	0.988	4246.	1.140	0.743	9383.	0.0087	0.088
725.0	8956.	----	----	0.	4246.		A			C.0	0.743	0.00009	0.00068	0.0095
0.025	0.0	46.0	67127.	0.	0.0	2456.2	P	0.987	4243.	1.140	0.743	9375.	0.0087	0.088
725.0	8948.	----	----	0.	4243.		A			C.0	0.743	0.00009	0.00068	0.0095
0.033	0.0	83.6	67091.	0.	0.0	2455.7	P	0.987	4241.	1.140	0.743	9367.	0.0087	0.088
725.0	8941.	----	----	0.	4241.		A			C.0	0.743	0.00009	0.00068	0.0095
0.042	0.0	117.3	67056.	0.	0.0	2455.2	P	0.986	4238.	1.140	0.743	9359.	0.0087	0.088
725.0	8933.	----	----	0.	4238.		A			C.0	0.743	0.00009	0.00068	0.0095

CLIMB TO 5000. FT. WITH MAXIMUM R/C AT MILITARY ENGINE RATING
** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH SPEED

TIME (HR)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PERF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/C (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PERF		AUX. ENG. BHP OR THRUST	

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY.

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CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN	
0.042	0.0	117.3	67056.	0.	89.9	2324.2	0	1.000	89.9	0.212	0.073	-0.9	11.3	5066.	1838.
725.0	4768.	----	----	----	4160.	----	----	0.0	----	----	----	----		----	
0.000131	0.000220	0.000025	0.000011	0.01172	0.00004	0.00121	0.000115	A	----	----	----	----	----	----	
0.051	0.82	157.0	67018.	1000.	90.9	2337.6	C	1.000	89.6	0.214	0.075	-0.9	11.1	5113.	1820.
725.0	4814.	----	----	----	4147.	----	----	0.0	----	----	----	----		----	
0.000134	0.000231	0.000026	0.000012	0.01195	0.00006	0.00142	0.000117	A	----	----	----	----	----	----	
0.060	1.67	195.0	66980.	2000.	91.9	2345.1	C	1.000	89.2	0.216	0.077	-0.9	10.8	5165.	1800.
725.0	4866.	----	----	----	4110.	----	----	0.0	----	----	----	----		----	
0.000138	0.000242	0.000027	0.000013	0.01222	0.00009	0.00167	0.000120	A	----	----	----	----	----	----	
0.069	2.53	233.0	66942.	3000.	91.9	2353.8	C	1.000	87.9	0.216	0.080	-0.9	10.7	5221.	1777.
725.0	4919.	----	----	----	4075.	----	----	0.0	----	----	----	----		----	
0.000140	0.000257	0.000027	0.000013	0.01245	0.00012	0.00186	0.000120	A	----	----	----	----	----	----	
0.077	3.40	271.2	66904.	4000.	92.9	2363.6	C	1.000	87.5	0.219	0.082	-0.9	10.4	5285.	1751.
725.0	4981.	----	----	----	4045.	----	----	0.0	----	----	----	----		----	
0.000145	0.000272	0.000026	0.000014	0.01279	0.00017	0.00216	0.000122	A	----	----	----	----	----	----	
0.086	4.27	309.7	66865.	5000.	92.9	2374.2	C	1.000	86.2	0.219	0.085	-0.8	10.3	5353.	1723.
725.0	5047.	----	----	----	4015.	----	----	0.0	----	----	----	----		----	
0.000148	0.000286	0.000028	0.000015	0.01309	0.00021	0.00241	0.000122	A	----	----	----	----	----	----	

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	ML	CT PRIME OVER SIGM	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR HP	T.ROTOR VTIP (FPS)	T.ROTOR RPM	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
0.038	4.29	309.7	[illegible]	5000.	165.6	2356.5	C	1.000	153.7	0.385	0.084	-2.6	.04168	9526.
725.0	9094.	-		----	3972.	----	----	0.0	----	----	----	----		----
0.000458	0.000164	[illegible]	0.	02923	0.00312	0.01561	0.000381	A	----	----	----	----	----	----
0.149	14.29		66625.	5000.	165.8	2356.4	C	1.000	153.9	0.386	0.084	-2.6	.04174	9526.
725.0	9095.		----	----	3972.	----	----	0.0	----	----	----	----		----
0.000458	0.000162	0.	0.003049	0.02923	0.00309	0.01554	0.000382	A	----	----	----	----	----	----
0.209	24.29	769.	66385.	5000.	166.0	2356.3	C	1.000	154.1	0.387	0.084	-2.7	.04180	9525.
725.0	9093.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000459	0.000161	0.000190	0.003048	0.02923	0.00306	0.01567	0.000383	A	----	----	----	----	----	----
0.269	34.29	1029.	66146.	5000.	166.3	2356.1	C	1.000	154.4	0.387	0.083	-2.7	.04186	9523.

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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OF POOR QUALITY

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725.0	9392.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000463	0.000159	0.000191	0.000048	0.02923	0.00304	0.01570	0.000384	A	----	----	----	----	---	----
0.329	44.29	1267.4	65507.	5000.	166.5	2356.2	C	1.000	154.6	0.388	0.0[illegible]	-2.7	.04192	9522.
725.0	9097.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000463	0.000158	0.000173	0.000046	0.02923	0.00301	0.01573	0.000385	A	----	----	----	----	----	----
0.399	54.29	1505.[illegible]	65665.	5000.	166.8	2355.2	C	1.000	154.8	0.388	0.083	-2.7	.04198	9521.
725.0	9093.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000461	0.000157	0.000194	0.000047	0.02923	0.00298	0.01575	0.000386	A	----	----	----	----	----	----
0.46[illegible]	64.29	1744.1	65433.	5000.	167.0	2356.1	C	1.000	155.0	0.389	0.082	-2.7	.04204	9520.
725.0	9091.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000461	0.000155	0.000195	0.000047	0.02923	0.00295	0.01578	0.000387	A	----	----	----	----	----	----
0.5[illegible]	74.29	1981.9	65193.	5000.	167.2	2356.0	C	1.000	155.2	0.389	0.082	-2.7	.04210	9518.
725.0	9087.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000462	0.000154	0.000196	0.000047	0.02923	0.00293	0.01581	0.000388	A	----	----	----	----	----	----
0.567	84.29	2219.4	64955.	5000.	167.5	2356.0	C	1.000	155.4	0.390	0.082	-2.8	.04216	9518.
725.0	9087.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000462	0.000153	0.000197	0.000046	0.02923	0.00290	0.01583	0.000389	A	----	----	----	----	----	----
0.629	94.29	2456.6	64718.	5000.	167.7	2355.9	C	1.000	155.7	0.390	0.082	-2.8	.04222	9516.
725.0	9088.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000463	0.000151	0.000198	0.000046	0.02922	0.00287	0.01586	0.000391	A	----	----	----	----	----	----
0.690	104.29	2693.5	64481.	5000.	167.9	2355.8	C	1.000	155.[illegible]	0.391	0.081	-2.8	.04228	9515.
725.0	9084.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000463	0.000150	0.000199	0.000046	0.02922	0.00284	0.01588	0.000392	A	----	----	----	----	----	----
0.74[illegible]	114.29	2930.0	64245.	5000.	168.1	2355.8	C	1.000	156.1	0.391	0.081	-2.8	.04234	9514.
725.0	9085.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000464	0.000149	0.000200	0.000045	0.02922	0.00281	0.01591	0.000393	A	----	----	----	----	----	----
0.797	124.29	3166.2	64008.	5000.	168.4	2355.7	C	1.000	156.3	0.392	0.081	-2.8	.04240	9514.
725.0	9083.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000464	0.000148	0.000201	0.000045	0.02922	0.00279	0.01593	0.000394	A	----	----	----	----	----	----
0.857	134.29	3402.1	63773.	5000.	168.6	2355.7	C	1.000	156.5	0.393	0.080	-2.8	.04245	9513.
725.0	9082.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000465	0.000146	0.000202	0.000045	0.02921	0.00276	0.01596	0.000395	A	----	----	----	----	----	----
0.926	144.29	3637.6	63537.	5000.	168.8	2355.6	C	1.000	156.7	0.393	0.080	-2.9	.04251	9512.
725.0	9081.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000465	0.000145	0.000203	0.000044	0.02921	0.00273	0.01598	0.000396	A	----	----	----	----	----	----
0.995	154.29	3872.8	63302.	5000.	169.0	2355.6	C	1.000	156.9	0.394	0.080	-2.9	.04257	9511.
725.0	9080.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000465	0.000144	0.000204	0.000044	0.02921	0.00270	0.01601	0.000397	A	----	----	----	----	----	----
1.065	164.29	4107.8	63067.	5000.	169.3	2355.5	C	1.000	157.1	0.394	0.079	-2.9	.04262	9510.
725.0	9079.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000466	0.000142	0.000205	0.000044	0.02920	0.00268	0.01603	0.000398	A	----	----	----	----	----	----
1.134	174.29	4342.4	62832.	5000.	169.5	2355.4	C	1.000	157.3	0.395	0.079	-2.9	.04268	9509.
725.0	9073.	----	----	----	3971.	----	----	0.0	----	----	----	----		----
0.000466	0.000141	0.000206	0.000043	0.02920	0.00265	0.01605	0.000399	A	----	----	----	----	----	----
1.1[illegible]	[illegible]	4577.[illegible]	[illegible]	5000.	169.7	2355.4	C	1.000	157.5	0.395	0.079	-2.9	.04274	9509.

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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725.0	9978.	----	----	----	3971.	----	----	0.0	----	----	----	----			----
0.000467	0.000143	0.000207	0.000043	0.02919	0.00262	0.01609	0.000400	A	----	----	----	----	----		----
1.222	194.29	4810.7	62364.	5000.	169.9	2355.3	6	1.000	157.7	0.396	0.079	-3.0	.0427		9507.
725.0	9977.	----	----	----	3971.	----	----	0.0	----	----	----	----			----
0.000467	0.000139	0.000208	0.000043	0.02919	0.00259	0.01613	0.000401	A	----	----	----	----	----		----
1.242	197.72	4890.6	62284.	5000.	170.0	2355.3	6	1.000	157.8	0.396	0.078	-3.0	.0428		9507.
725.0	9977.	----	----	----	3971.	----	----	0.0	----	----	----	----			----
0.000467	0.000138	0.000209	0.000043	0.02919	0.00258	0.01613	0.000401	A	----	----	----	----	----		----

DESCEND TO H = 2000. FT. R = 200.00 N.MI. AT CONSTANT TAS

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (K)	PRIM. ENG. CODE	PRIM. ENG. PEHP	IAS (KTS)	ML	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/S (FPM)
MRVTIP VTIP (FPS)	MRHP HHP	TRVTIP VTIP (FPS)	TRHP HHP	PROP VTIP (FPS)	PRIM. ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHP	AUX. ENG. BHP OR THRUST		
CPPR	CPIND	CPPAR	CPNLD	CDO	DELCDS	DELCDM	CXR	ACTLIM CODE	J	CP	CT	CLW	CDW	RN	
1.242	197.72	4890.6	62284.	5000.	115.0	1740.0	T	0.783	106.8	0.268	0.077	10.9	-12.2	0.	2460.
725.0	-145.	----	----	----	1209.	----	----	0.0	----	----	----	----		----	
0.000183	0.000195	-.000414	0.000023	0.01480	0.00003	0.00429	-.001452	A	----	----	----	----	----	----	
1.243	198.48	4898.8	62276.	4000.	115.0	1740.0	T	0.783	106.8	0.268	0.077	10.9	-12.2	0.	2460.
725.0	-145.	----	----	----	1209.	----	----	0.0	----	----	----	----		----	
0.000183	0.000194	-.000414	0.000023	0.01479	0.00003	0.00429	-.001452	A	----	----	----	----	----	----	
1.253	199.24	4907.0	62268.	3000.	115.0	1740.0	T	0.783	106.8	0.268	0.077	10.9	-12.2	0.	2460.
725.0	-145.	----	----	----	1209.	----	----	0.0	----	----	----	----		----	
0.000183	0.000194	-.000414	0.000023	0.01479	0.00003	0.00428	-.001452	A	----	----	----	----	----	----	
1.262	200.00	4915.2	62259.	2000.	115.0	1740.0	T	0.783	106.8	0.268	0.077	10.9	-12.2	0.	2460.
725.0	-145.	----	----	----	1209.	----	----	0.0	----	----	----	----		----	
0.000183	0.000194	-.000414	0.000023	0.01479	0.00003	0.00428	-.001452	A	----	----	----	----	----	----	

LOITER FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (K)	PRIM. ENG. CODE	PRIM. ENG. PEHP	IAS (KTS)	ML	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	TOTAL FUEL FLOW (LBS/HR)	BHP
MRVTIP VTIP (FPS)	MRHP HHP	TRVTIP VTIP (FPS)	TRHP HHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHP		AUX. ENG. BHP OR THRUST
CPPR	CPIND	CPPAR	CPNLD	CDO	DELCDS	DELCDM	CXR	ACTLIM	J	CF	CT	CLW	CDW	RN

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

3897

								CODE						
1.262	200.00	4915.2	62259.	2000.	91.6	2058.4	P	0.498	88.9	0.213	0.072	-0.9	2598.	4727.
725.0	4439.	----	----	----	2598.	----	----	0.0	----	----	----	----	----	----
0.000134	0.000212	0.003026	0.000012	0.01192	0.00004	0.00142	0.000117	A	----	----	----	----	----	----
1.287	200.00	4980.1	62194.	2000.	91.6	2058.0	P	0.497	88.9	0.213	0.072	-0.9	2596.	4721.
725.0	4434.	----	----	----	2596.	----	----	0.0	----	----	----	----	----	----
0.000134	0.000212	0.003026	0.000011	0.01192	0.00004	0.00142	0.000117	A	----	----	----	--	----	----

DESCEND TO H = 1000. FT. AT CONSTANT TAS (SPIRAL DESCENT PATH - NO RANGE CREDIT)

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (F)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/S (F/M)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST	
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN	
1.287	200.00	4980.1	62194.	2000.	70.0	1948.1	P	0.311	68.0	0.163	0.072	7.6	-8.1	2951.	1000.
725.0	2717.	----	----	----	2086.	----	----	0.0	----	----	----	----		----	
0.000113	0.000268	-.000153	0.000006	0.01088	0.0	0.00047	-.000929	A	----	----	----	----	----	----	
1.295	200.58	4997.5	62177.	1500.	70.0	1948.0	P	0.311	68.0	0.163	0.072	7.6	-8.1	2950.	1000.
725.0	2716.	----	----	----	2085.	----	----	0.0	----	----	----	----		----	
0.000113	0.000268	-.000153	0.000006	0.01088	0.0	0.00047	-.000929	A	----	----	----	----	----	----	
1.304	201.16	5014.9	62160.	1000.	70.0	1947.9	P	0.311	68.0	0.163	0.072	7.6	-8.1	2949.	1000.
725.0	2715.	----	----	----	2085.	----	----	0.0	----	----	----	----		----	
0.000113	0.000268	-.000153	0.000006	0.01088	0.0	0.00047	-.000929	A	----	----	----	----	----	----	

TRANSFER ALTITUDE TO 0. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.304	200.00	5014.9	62160.	1000.
1.304	200.00	5014.9	62160.	0.

TAKEOFF, HOVER, OR LAND AT T/W = 1.140 FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELDCM	FMI	CPPRO	CPIND	CDO

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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C-3

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1.334	200.00	5014.9	62160.	0.	0.0	2390.8	P	0.876	3886.	1.140	0.748	8316.	0.0081	0.081
725.0	7921.	----	----	0.	3886.	----	A			C.0	0.748	0.00009	0.00060	0.0094
1.312	200.00	5047.5	62127.	0.	0.0	2390.4	P	C.875	3884.	1.140	0.748	8309.	0.0080	0.081
725.0	7914.	----	----	0.	3884.	----	A			C.0	0.748	0.00009	0.0006C	0.0094
1.323	200.00	5080.2	62094.	0.	0.0	2390.0	P	0.874	3882.	1.140	0.748	8303.	0.0080	0.081
725.0	7938.	----	----	0.	3882.	----	A			C.0	0.748	0.00009	0.00059	0.0094

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PEHF	AUX. ENG. FUEL FLOW (LBS/HP)
1.320	200.00	5080.2	62094.	0.	0.0	1725.0	T	0.0	739.	----	----	----	----
1.337	200.00	5092.5	62082.	0.	0.0	1725.0	T	0.0	739.	----	----	----	----

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.337	200.00	5092.5	62082.	0.
1.337	200.00	5092.5	62082.	5000.

CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF 0.0 KNOTS FOR RESERVEFUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	ML	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDJ	DELCUS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
1.337	200.00	5092.5	62082.	5000.	150.0	2210.0	P	0.768	139.2	0.349	0.078	-2.3	.04617	7289.
725.0	6924.	----	----	----	3251.	----	----	0.0	----	----	----	----		----
0.000325	0.000156	0.000130	0.000043	0.02241	0.00127	0.01065	0.000312	A	----	----	----	----	----	----
1.404	210.00	5309.1	61865.	5000.	150.0	2208.6	P	C.766	139.2	C.349	0.078	-2.3	.04627	7266.
725.0	6903.	----	----	----	3244.	----	----	0.0	----	----	----	----		----
0.000324	0.000155	0.000130	0.000043	0.02236	0.00124	0.01062	0.000312	A	----	----	----	----	----	----
1.471	220.00	5525.2	61649.	5000.	150.0	2207.1	P	0.763	139.2	0.349	0.078	-2.3	.04637	7244.
725.0	6882.	----	----	----	3237.	----	----	0.0	----	----	----	----		----
0.000324	0.000154	0.000130	0.000043	0.02230	0.00122	0.01059	0.000312	A	----	----	----	----	----	----
1.537	230.00	5740.9	61434.	5000.	150.0	2205.7	P	0.761	139.2	0.349	0.077	-2.3	.04647	7223.

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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725.0	6860.	----	----	----	3230.	----	----	0.0	----	----	----	----		----
0.000323	0.000152	0.000130	0.000043	0.02225	0.00120	0.01056	0.000312	A	----	----	----	----	----	----
1.634	240.00	5956.1	61218.	5000.	150.0	2204.2	P	0.759	139.2	0.349	0.077	-2.3	.04657	7201.
725.0	6339.	----	----	----	3223.	----	----	0.0	----	----	----	----		----
0.000322	0.000151	0.000130	0.000042	0.02219	0.00117	0.01053	0.000312	A	----	----	----	----	----	----
1.671	250.00	6170.8	61004.	5000.	150.0	2202.8	P	0.756	139.2	0.349	0.077	-2.4	.04667	7179.
725.0	6018.	----	----	----	3216.	----	----	0.0	----	----	----	----		----
0.000321	0.000150	0.000130	0.000042	0.02214	0.00115	0.01050	0.000312	A	----	----	----	----	----	----

LOITER FOR 0.333 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (K)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	TOTAL FUEL FLOW (LBS/HR)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPAUD	CDO	DELCUS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
1.337	250.00	6170.8	62082.	5000.	92.5	2061.9	P	0.513	85.8	0.215	0.078	-0.9	2520.	4864.
725.0	4573.	----	----	----	2520.	----	----	0.0	----	----	----	----		----
0.000142	0.000250	0.000026	0.000013	0.01262	0.00010	0.00206	0.000119	A	----	----	----	----	----	----
1.437	250.00	6422.8	61830.	5000.	92.5	2060.4	P	0.510	85.8	0.215	0.078	-0.9	2512.	4839.
725.0	4549.	----	----	----	2512.	----	----	0.0	----	----	----	----		----
0.000142	0.000248	0.000026	0.000013	0.01261	0.00010	0.00205	0.000119	A	----	----	----	----	----	----
1.537	250.00	6674.0	61579.	5000.	92.5	2058.8	P	0.507	85.8	0.215	0.078	-0.9	2504.	4815.
725.0	4525.	----	----	----	2504.	----	----	0.0	----	----	----	----		----
0.000142	0.000246	0.000026	0.000013	0.01259	0.00009	0.00204	0.000119	A	----	----	----	----	----	----
1.637	250.00	6924.4	61328.	5000.	92.5	2057.3	P	0.505	85.8	0.215	0.078	-0.9	2497.	4791.
725.0	4501.	----	----	----	2497.	----	----	0.0	----	----	----	----		----
0.000142	0.000244	0.000026	0.000013	0.01258	0.00009	0.00203	0.000119	A	----	----	----	----	----	----
1.670	250.00	7006.8	61246.	5000.	92.5	2056.8	P	0.504	85.8	0.215	0.077	-0.9	2495.	4783.
725.0	4494.	----	----	----	2495.	----	----	0.0	----	----	----	----		----
0.000142	0.000244	0.000026	0.000013	0.01257	0.00009	0.00202	0.000119	A	----	----	----	----	----	----

MISSION FUEL REQUIRED = 5092.45
RESERVE FUEL REQUIRED = 1914.36
TOTAL FUEL REQUIRED = 7006.81

TABLE 3.1 BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

(37) 3897

H E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM 8-91

MISSION PERFORMANCE DATA

TAKEOFF, HOVER, OR LAND AT PEHF = 1.000 FOR 0.001 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR HHP	T.ROTOR VTIP (FPS)	T.ROTOR HHP	VRC RFP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELUCM	FMI	CPPRO	CPIND	CDO
0.0	0.0	0.0	67175.	0.	0.0	2463.6	Q	1.000	4284.	1.146	0.743	9461.	0.0087	0.089
725.0	9032.	----	----	0.	4284.	----	A			C.0	0.743	0.00009	0.00069	0.0095
0.000	0.0	2.1	67173.	C.	0.0	2463.6	Q	1.000	4284.	1.146	0.743	9460.	0.0087	0.089
725.0	9031.	----	----	0.	4284.	----	A			C.0	0.743	0.00009	0.00069	0.0095
0.001	0.0	4.3	67171.	0.	0.0	2463.6	Q	1.000	4284.	1.146	0.743	9460.	0.0087	0.089
725.0	9031.	----	----	0.	4284.	----	A			C.0	0.743	0.00009	0.00069	0.0095

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.001	0.0	4.3	67171.	0.
0.001	0.0	4.3	67171.	5000.

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR HHP	T.ROTOR VTIP (FPS)	T.ROTOR HHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	ALX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPRUD	CDO	CDS	DELCDM	CXR	RCTLIM CODE	J	CF	CT	CLW	CDW	RN
0.001	0.0	4.3	67171.	5000.	165.2	2356.6	C	1.000	153.4	C.385	0.085	-2.6	.04160	9525.
725.0	9094.	----	----	----	3973.	----	----	0.0	----	----	----	----		----
0.000457	0.000165	0.000187	0.000049	0.02923	0.00316	0.01558	0.000379	A	----	----	----	----	----	----

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

(23) 3897

0.331	5.00	124.5	67050.	5003.	165.4	2356.5	C	1.000	153.5	C.385	0.084	-2.6	.04163	9525.
725.0	9094.	----	----	----	3972.	----	----	0.0	----	----	----	----		----
0.000457	0.000165	0.000187	0.000049	0.02923	0.00314	0.01559	0.000380	A	----	----	----	----	----	----

MISSION FUEL REQUIRED = 124.49
RESERVE FUEL REQUIRED = 0.0
TOTAL FUEL REQUIRED = 124.49

****

END OF SUCCESSFUL CASE

****

TABLE 3.1. BASELINE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674
-5H
(8)

M E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM 8-91

MISSION PERFORMANCE DATA

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PEHF	AUX. ENG. FUEL FLOW (LBS/HR)
0.0	0.0	0.0	74227.	0.	0.0	1725.0	T	0.0	882.	----	----	----	
0.017	0.0	14.7	74213.	0.	0.0	1725.0	T	0.0	882.	----	----	----	

TAKEOFF, HOVER, OR LAND AT T/W = 1.140 FOR 0.033 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	ROTLIM CODE			DELDCN	FMI	CPPRO	CPIND	CDO
.017	0.0	14.7	74213.	0.	0.0	2456.1	P	0.987	5065.	1.140	0.687	11190.	0.0112	0.070
-0.0	10709.	----	----	0.	5065.		A			0.0	0.687	0.00014	0.00108	0.0093
0.025	0.0	57.2	74170.	0.	0.0	2455.6	P	0.986	5062.	1.140	0.687	11180.	0.0112	0.070
640.0	10699.	----	----	0.	5062.		A			0.0	0.687	0.00014	0.00108	0.0093
0.033	0.0	99.8	74128.	0.	0.0	2455.1	P	0.986	5058.	1.140	0.687	11170.	0.0112	0.070
640.0	10690.	----	----	0.	5058.		A			0.0	0.687	0.00014	0.00107	0.0093
0.042	0.0	142.3	74085.	0.	0.0	2454.6	P	0.985	5055.	1.140	0.687	11161.	0.0111	0.070
643.0	10680.	----	----	0.	5055.		A			0.0	0.687	0.00014	0.00107	0.0093

CLIMB TO 5000. FT. WITH MAXIMUM R/C AT MILITARY ENGINE RATING
** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH SPEED

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	ML	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/C (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF	AUX. ENG. BHP OR THRUST		

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY.

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CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	RCTLIM CODE	J	CP	CT	CLM	CDM	RN
0.042	0.0	142.3	74085.	0.	93.1	2323.9	Q	1.000	93.1	0.248	0.058	-0.9	12.2	5842. 2062.
640.0	5522.	----	----	----	4965.	----	----	0.0	----	----	----	----		----
0.003201	0.000313	0.000039	0.000037	0.01349	0.00000	0.00002	0.000152	A	----	----	----	----	----	----
0.050	0.76	182.4	74045.	1000.	94.1	2337.0	C	1.000	92.8	0.251	0.060	-0.9	12.0	5865. 2056.
640.0	5544.	----	----	----	4947.	----	----	0.0	----	----	----	----		----
0.003203	0.000328	0.000041	0.000039	0.01051	0.00001	0.00004	0.000155	A	----	----	----	----	----	----
0.058	1.53	222.5	74005.	2000.	95.1	2344.6	Q	1.000	92.4	0.254	0.062	-0.9	11.9	5894. 2047.
640.0	5571.	----	----	----	4902.	----	----	0.0	----	----	----	----		----
0.000204	0.000345	0.000042	0.000042	0.01054	0.00002	0.00006	0.000158	A	----	----	----	----	----	----
0.066	2.32	262.4	73965.	3000.	95.1	2353.2	C	1.000	91.0	0.254	0.064	-0.9	11.8	5924. 2036.
640.0	5601.	----	----	----	4861.	----	----	0.0	----	----	----	----		----
0.000204	0.000365	0.000042	0.000043	0.01056	0.00003	0.00007	0.000158	A	----	----	----	----	----	----
0.074	3.10	302.2	73925.	4000.	96.1	2362.5	C	1.000	90.6	0.256	0.065	-0.9	11.6	5961. 2023.
640.0	5636.	----	----	----	4825.	----	----	0.0	----	----	----	----		----
0.000206	0.000384	0.000044	0.000046	0.01060	0.00004	0.00010	0.000161	A	----	----	----	----	----	----
0.083	3.91	341.5	73885.	5000.	97.1	2373.4	C	1.000	90.2	0.259	0.067	-0.9	11.4	6002. 2008.
640.0	5677.	----	----	----	4790.	----	----	0.0	----	----	----	----		----
0.000208	0.000403	0.000045	0.000048	0.01066	0.00006	0.00014	0.000165	A	----	----	----	----	----	----

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	PL	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST
CPPRC	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	RCTLIM CODE	J	CP	CT	CLM	CDM	RN
0.083	3.91	341.9	73885.	5000.	181.2	2352.3	Q	1.000	168.2	0.478	0.067	-3.0	.03827	11405.
640.0	10917.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000619	0.000219	0.000447	0.000071	0.02013	0.00372	0.00591	0.000561	A	----	----	----	----	----	----
0.139	13.91	603.3	73624.	5000.	181.3	2352.2	Q	1.000	168.3	0.478	0.067	-3.0	.03830	11402.
640.0	10914.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000618	0.000218	0.000449	0.000071	0.02010	0.00369	0.00591	0.000562	A	----	----	----	----	----	----
0.191	23.91	864.4	73363.	5000.	181.5	2352.2	Q	1.000	168.5	0.479	0.067	-3.0	.03834	11399.
640.0	10912.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000618	0.000216	0.000451	0.000070	0.02007	0.00366	0.00592	0.000563	A	----	----	----	----	----	----
0.248	33.91	1125.2	73102.	5000.	181.7	2352.1	C	1.000	168.6	0.479	0.066	-3.1	.03837	11396.

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674 -5H (10)

640.0	10909.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000618	0.000214	0.000453	0.000070	0.02005	0.00362	0.00593	0.000565	A	----	----	----	----	----	----
0.303	43.91	1385.8	72841.	5000.	181.8	2352.1	G	1.000	168.8	0.480	0.066	-3.1	.03841	11394.
640.0	10906.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000618	0.000212	0.000455	0.000070	0.02002	0.00359	0.00594	0.000566	A	----	----	----	----	----	----
0.358	53.91	1646.2	72581.	5000.	182.0	2352.1	G	1.000	168.9	0.480	0.066	-3.1	.03844	11391.
640.0	10904.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000617	0.000211	0.000457	0.000070	0.02000	0.00356	0.00594	0.000567	A	----	----	----	----	----	----
0.413	63.91	1906.4	72321.	5000.	182.1	2352.0	G	1.000	169.1	0.480	0.066	-3.1	.03847	11388.
640.0	10901.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000617	0.000209	0.000458	0.000069	0.01997	0.00352	0.00595	0.000567	A	----	----	----	----	----	----
0.468	73.91	2166.3	72061.	5000.	182.3	2352.0	G	1.000	169.2	0.481	0.066	-3.1	.03851	11386.
640.0	10899.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000617	0.000207	0.000460	0.000069	0.01994	0.00349	0.00596	0.000569	A	----	----	----	----	----	----
0.523	83.91	2426.0	71801.	5000.	182.5	2351.9	G	1.000	169.4	0.481	0.065	-3.1	.03854	11383.
640.0	10896.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000617	0.000206	0.000462	0.000069	0.01992	0.00346	0.00596	0.000569	A	----	----	----	----	----	----
0.578	93.91	2685.4	71542.	5000.	182.6	2351.9	G	1.000	169.5	0.482	0.065	-3.2	.03858	11381.
640.0	10894.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000616	0.000204	0.000464	0.000069	0.01989	0.00342	0.00597	0.000570	A	----	----	----	----	----	----
0.632	103.91	2944.8	71282.	5000.	182.8	2351.8	G	1.000	169.7	0.482	0.065	-3.2	.03861	11379.
640.0	10892.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000616	0.000202	0.000466	0.000068	0.01987	0.00339	0.00598	0.000571	A	----	----	----	----	----	----
0.687	113.91	3203.6	71023.	5000.	182.9	2351.8	G	1.000	169.8	0.482	0.065	-3.2	.03865	11377.
640.0	10890.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000616	0.000201	0.000468	0.000068	0.01984	0.00336	0.00598	0.000572	A	----	----	----	----	----	----
0.742	123.91	3462.4	70764.	5000.	183.1	2351.8	G	1.000	170.0	0.483	0.064	-3.2	.03868	11375.
640.0	10888.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000616	0.000199	0.000470	0.000068	0.01981	0.00333	0.00599	0.000573	A	----	----	----	----	----	----
0.796	133.91	3720.9	70506.	5000.	183.2	2351.7	G	1.000	170.1	0.483	0.064	-3.2	.03871	11373.
640.0	10886.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000615	0.000198	0.000472	0.000068	0.01979	0.00329	0.00600	0.000574	A	----	----	----	----	----	----
0.851	143.91	3979.3	70248.	5000.	183.4	2351.7	G	1.000	170.2	0.484	0.064	-3.2	.03875	11371.
640.0	10884.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000615	0.000196	0.000473	0.000068	0.01976	0.00326	0.00600	0.000575	A	----	----	----	----	----	----
0.905	153.91	4237.3	69989.	5000.	183.6	2351.6	G	1.000	170.4	0.484	0.064	-3.3	.03878	11369.
640.0	10882.	----	----	----	4733.	----	----	0.0	----	----	----	----		----
0.000615	0.000194	0.000475	0.000067	0.01974	0.00323	0.00601	0.000576	A	----	----	----	----	----	----
0.960	163.91	4495.2	69732.	5000.	183.7	2351.6	G	1.000	170.5	0.485	0.063	-3.3	.03881	11367.
640.0	10880.	----	----	----	4733.	----	----	0.0	----	----	----	----		----
0.000615	0.000193	0.000477	0.000067	0.01971	0.00320	0.00602	0.000577	A	----	----	----	----	----	----
1.014	173.91	4752.9	69474.	5000.	183.9	2351.5	G	1.000	170.7	0.485	0.063	-3.3	.03885	11365.
640.0	10878.	----	----	----	4733.	----	----	0.0	----	----	----	----		----
0.000614	0.000191	0.000479	0.000067	0.01968	0.00316	0.00602	0.000578	A	----	----	----	----	----	----
1.069	183.91	5010.3	69216.	5000.	184.0	2351.5	G	1.000	170.8	0.485	0.063	-3.3	.03888	11363.

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674 -5H (11)

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640.0     10877.    ----      ----      ----     4733.     ----      ----     0.0      ----    ----    ----    ----            ----
0.000614  0.000190  0.000481  0.000067  0.01966  0.00313   0.00603   0.000579  A       ----    ----    ----    ----    ----    ----

1.123     193.91    5267.5    68959.    5000.    184.2     2351.5    C        1.000    171.0   0.486   0.063   -3.3    .03891  11362.
640.0     10875.    ----      ----      ----     4733.     ----      ----     0.0      ----    ----    ----    ----            ----
0.000614  0.000188  0.000483  0.000066  0.01963  0.00310   0.00604   0.000580  A       ----    ----    ----    ----    ----    ----

1.143     197.62    5362.9    68864.    5000.    184.2     2351.4    C        1.000    171.0   0.486   0.063   -3.3    .03892  11361.
640.0     10875.    ----      ----      ----     4733.     ----      ----     0.0      ----    ----    ----    ----            ----
0.000614  0.000187  0.000483  0.000066  0.01962  0.00309   0.00604   0.000581  A       ----    ----    ----    ----    ----    ----
```

DESCEND TO H = 2000. FT. ,R = 200.00 N.MI. AT CONSTANT TAS

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                                                           PRIM.     PRIM.     PRIM.                    CT PRIME
                    FUEL                PRES.              TURB.     ENG.      ENG.                     OVER     ALPHA
TIME      RANGE     USED      WEIGHT    ALT.     TAS       TEMP.     CODE      PEMF     EAS     MU      SIGMA    D/L     GAMMA   BHP     R/S
(HRS)     (N.M.)    (LBS)     (LBS.)    (FT)     (KTS)     (R)                          (KTS)                    (DEG)   (DEG)           (FPM)

                                                                                                 AUX.    AUX.     AUX.            AUX.
M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR   PROP     PRIM.ENG  BHP       ETAP               AUX. ENG. TURB.  ENG.     ENG.            ENG. BHP
VTIP      BHP       VTIP      BHP       VTIP     FUEL FLOW AUX       PRCP      TALX/T   FUEL FLOW TEMP.  CODE     PEMF            OR THRUST
(FPS)               (FPS)               (FPS)    (LBS/HR)                               (LBS/HR)

CPPRO     CPIND     CPPAR     CPNUD     CDJ      DELCOS    DELCOM    CXR       RCTLIM   J       CP      CT      CLW     CDW     RN
                                                                               CODE

1.143     197.62    5362.9    68864.    5000.    115.0     1740.0    T         0.782    106.8   0.303   0.061   10.4    -11.7   -0.  2363.
640.0     -146.     ----      ----      ----     1443.     ----      ----      0.0      ----    ----    ----    ----            ----
0.000231  0.000287  -.000602  0.000066  0.01086  0.00000   0.00037   -.001792  A        ----    ----    ----    ----    ----    ----

1.150     198.41    5373.0    68854.    4000.    115.0     1740.0    T         0.782    106.8   0.303   0.061   10.4    -11.7   0.   2363.
640.0     -145.     ----      ----      ----     1443.     ----      ----      0.0      ----    ----    ----    ----            ----
0.000231  0.000287  -.000602  0.000066  0.01086  0.00000   0.00037   -.001791  A        ----    ----    ----    ----    ----    ----

1.157     199.21    5383.2    68843.    3000.    115.0     1740.0    T         0.782    106.8   0.303   0.061   10.4    -11.7   0.   2363.
640.0     -145.     ----      ----      ----     1443.     ----      ----      0.0      ----    ----    ----    ----            ----
0.000231  0.000287  -.000602  0.000066  0.01086  0.00000   0.00037   -.001791  A        ----    ----    ----    ----    ----    ----

1.164     200.00    5393.4    68833.    2000.    115.0     1740.0    T         0.782    106.8   0.303   0.061   10.4    -11.7   0.   2363.
640.0     -145.     ----      ----      ----     1443.     ----      ----      0.0      ----    ----    ----    ----            ----
0.000231  0.000287  -.000602  0.000066  0.01086  0.00000   0.00037   -.001791  A        ----    ----    ----    ----    ----    ----
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LOITER FOR 0.025 HRS.

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                                                           PRIM.     PRIM.     PRIM.                    CT PRIME
                    FUEL                PRES.              TURB.     ENG.      ENG.                     OVER     ALPHA   TOTAL
TIME      RANGE     USED      WEIGHT    ALT.     TAS       TEMP.     CODE      PEMF     EAS     MU      SIGMA    D/L     FUEL FLOW  BHP
(HRS)     (N.M.)    (LBS)     (LBS.)    (FT)     (KTS)     (R)                          (KTS)                    (DEG)   (LBS/HR)

                                                                                                 AUX.    AUX.     AUX.                AUX.
M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR   PROP     PRIM.ENG  BHP       ETAP               AUX. ENG. TURB.  ENG.     ENG.                ENG. BHP
VTIP      BHP       VTIP      BHP       VTIP     FUEL FLOW AUX       PRCP      TALX/T   FUEL FLOW TEMP.  CODE     PEMF                OR THRUST
(FPS)               (FPS)               (FPS)    (LBS/HR)                               (LBS/HR)

CPPRO     CPIND     CPPAR     CPNUD     CDJ      DELCOS    DELCOM    CXR       RCTLIM   J       CP      CT      CLW     CDW     RN
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TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

CODE

5674 -5H (12)

1.164	200.00	5393.4	68833.	2000.	95.6	2047.2	P	0.480	92.8	0.252	0.057	-1.0	3037.		5437.
640.0	5128.	----	----	----	3037.	----	----	0.0	----	----	----	----			----
0.000233	0.000330	0.000041	0.000038	0.01051	0.00000	0.00004	0.000156	A	----	----	----	----	----		----
1.189	200.00	5469.3	68757.	2000.	94.6	2046.7	P	0.479	91.8	0.249	0.057	-1.0	3035.		5426.
640.0	5117.	----	----	----	3035.	----	----	0.0	----	----	----	----			----
0.000202	0.000302	0.000040	0.000037	0.01051	0.00000	0.00004	0.000153	A	----	----	----	----	----		----

DESCEND TO H = 1000. FT. AT CONSTANT TAS (SPIRAL DESCENT PATH - NO RANGE CREDIT)

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/S (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF	AUX. ENG. BHP OR THRUST		
CPPRO	CPIND	CPPAR	CPNUD	CCJ	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLM	CDM	RN	
1.189	200.00	5469.3	68757.	2000.	70.0	1946.7	P	0.309	68.0	0.185	0.?57	7.6	-8.1	3497.	1000.
640.0	3246.	----	----	----	2482.	----	----	0.0	----	----	----	----		----	
0.000180	0.000397	-.000224	0.000016	0.01040	0.0	0.0	-.001197	A	----	----	----	----	----	----	
1.198	200.58	5490.0	68737.	1500.	70.0	1946.6	P	0.308	68.0	0.185	0.057	7.6	-8.1	3495.	1000.
640.0	3245.	----	----	----	2482.	----	----	0.0	----	----	----	----		----	
0.000180	0.000397	-.000224	0.000016	0.01040	0.0	0.0	-.001196	A	----	----	----	----	----	----	
1.206	201.16	5510.7	68716.	1000.	70.0	1946.5	P	0.308	68.0	0.185	0.057	7.6	-8.1	3494.	1000.
640.0	3243.	----	----	----	2481.	----	----	0.0	----	----	----	----		----	
0.000180	0.000397	-.000224	0.000016	0.01040	0.0	0.0	-.001196	A	----	----	----	----	----	----	

TRANSFER ALTITUDE TO 0. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USFD (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.206	200.00	5510.7	68716.	1000.
1.206	200.00	5510.7	68716.	0.

TAKEOFF, HOVER, OR LAND AT T/W = 1.140 FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELDCM	FMI	CPPRO	CPIND	CDO

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

1.206	200.00	5510.7	68716.	0.	0.0	2391.0	P	0.876	4640.	1.140	0.691	9930.	0.0103	0.065
640.0	9486.	----	----	0.	4640.	----	A			0.0	0.691	0.00014	0.00094	0.0092
1.215	200.00	5549.7	68677.	0.	0.0	2390.5	P	0.875	4637.	1.140	0.691	9921.	0.0103	0.065
643.0	9478.	----	----	0.	4637.	----	A			0.0	0.691	0.00014	0.00094	0.0092
1.223	200.00	5586.6	68638.	0.	0.0	2390.1	P	0.875	4634.	1.140	0.691	9912.	0.0103	0.065
640.0	9469.	----	----	0.	4634.	----	A			0.0	0.691	0.00014	0.00094	0.0092

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PEMF	AUX. ENG. FUEL FLOW (LBS/HR)
1.223	200.00	5586.6	68639.	0.	0.0	1725.0	T	0.0	882.	----	----	----	----
1.240	200.00	5603.3	68623.	0.	0.0	1725.0	T	0.0	882.	----	----	----	----

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(13)

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.[illegible]	200.00	5603.3	68623.	0.
[illegible]	200.00	5603.3	68623.	5000.

CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF 0.0 KNOTS FOR RESERVEFUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
N.ROTOR VTIP (FPS)	N.ROTOR BHP	T.ROTOR VTIP (FPS)	T.ROTOR BHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUO	CDO	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLM	CDM	RN
1.240	200.00	5633.3	68623.	5000.	164.5	2189.5	P	0.740	152.7	0.434	0.062	-2.7	.04365	8381.
640.0	7984.	----	----	----	3773.	----	----	0.0	----	----	----	----		----
0.000425	0.000208	0.000292	0.000067	0.01521	0.00132	0.00339	0.000463	A	----	----	----	----	----	----
1.300	210.00	5832.4	68394.	5000.	164.5	2188.4	P	0.738	152.7	0.434	0.062	-2.7	.04373	8360.
640.0	7964.	----	----	----	3766.	----	----	0.0	----	----	----	----		----
0.000424	0.000207	0.000292	0.000066	0.01518	0.00130	0.00338	0.000463	A	----	----	----	----	----	----
1.361	220.00	6061.1	68165.	5000.	164.5	2187.2	P	0.736	152.7	0.434	0.062	-2.7	.04380	8339.
640.0	7943.	----	----	----	3760.	----	----	0.0	----	----	----	----		----
0.000423	0.000206	0.000292	0.000066	0.01515	0.00128	0.00337	0.000463	A	----	----	----	----	----	----
1.422	230.00	6289.4	67937.	5000.	164.5	2186.1	P	0.734	152.7	0.434	0.062	-2.7	.04388	8318.

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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640.0	7923.	----	----	----	3753.	----	----	0.0	----	----	----	----	----	----
0.303422	0.000204	0.000292	0.000066	0.01511	0.00126	0.00336	0.000463	A	----	----	----	----	----	----
1.483	240.00	6517.3	67705.	5000.	164.5	2184.9	P	0.732	152.7	0.434	0.062	-2.7	.04396	8298.
640.0	7903.	----	----	----	3746.	----	----	0.0	----	----	----	----		----
0.000421	0.000203	0.000292	0.000066	0.01508	0.00124	0.00335	0.000463	A	----	----	----	----	----	----
1.544	250.00	6744.8	67482.	5000.	164.5	2183.3	P	0.731	152.7	0.434	0.061	-2.7	.04404	8277.
640.0	7843.	----	----	----	3740.	----	----	0.0	----	----	----	----		----
0.303421	0.000202	0.000292	0.000065	0.01505	0.00121	0.00334	0.000463	A	----	----	----	----	----	----

LOITER FOR 0.333 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	TOTAL FUEL FLOW (LBS/HR)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPAUD	CCO	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
1.240	250.00	6744.8	68623.	5000.	96.5	2045.1	P	0.485	89.5	0.254	0.063	-0.9	2911.	5496.
640.0	5186.	----	----	----	2911.	----	----	0.0	----	----	----	----		----
0.000205	0.000354	0.000043	0.000043	0.01058	0.00002	0.00010	0.000159	A	----	----	----	----	----	----
1.340	250.00	7035.5	68332.	5000.	96.5	2043.7	P	0.483	89.5	0.254	0.062	-0.9	2903.	5469.
640.0	5160.	----	----	----	2903.	----	----	0.0	----	----	----	----		----
0.000205	0.000351	0.000043	0.000042	0.01058	0.00002	0.00009	0.000159	A	----	----	----	----	----	----
1.440	250.00	7326.2	68042.	5000.	96.5	2042.3	P	0.480	89.5	0.254	0.062	-0.9	2895.	5443.
640.0	5134.	----	----	----	2895.	----	----	0.0	----	----	----	----		----
0.000205	0.000346	0.000043	0.000042	0.01058	0.00002	0.00009	0.000159	A	----	----	----	----	----	----
1.540	250.00	7615.7	67752.	5000.	96.5	2040.9	P	0.478	89.5	0.254	0.062	-0.9	2887.	5416.
640.0	5108.	----	----	----	2887.	----	----	0.0	----	----	----	----		----
0.000205	0.000345	0.000043	0.000042	0.01058	0.00002	0.00009	0.000159	A	----	----	----	----	----	----
1.573	250.00	7710.9	67657.	5000.	96.5	2040.4	P	0.477	89.5	0.254	0.062	-0.9	2884.	3408.
640.0	5100.	----	----	----	2884	----	----	0.0	----	----	----	----		----
0.000205	0.000344	0.000043	0.000042	0.01057	0.00002	0.00009	0.000159	A	----	----	----	----	----	----

MISSION FUEL REQUIRED = 5603.06
RESERVE FUEL REQUIRED = 2107.88
TOTAL FUEL REQUIRED = 7710.93

TABLE 3.2. -5 PNdB DERIVATIVE HELIC[illegible]R MISSION TIME HISTORY. (CONTINUED)

NOISE DERIVATIVE HELICOPTERS -5PNDB VT#640 SOLD RATIO #1.06 PAGE 9

5674
-5H

(15)

M E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM B-91

MISSION PERFORMANCE DATA

TAKEOFF, HOVER, OR LAND AT PETF = 1.000 FOR 0.001 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR SHP	T.ROTOR VTIP (FPS)	T.ROTOR SHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELOCM	FMI	CPPRO	CPIND	CDO
0.0	0.0	0.0	74227.	0.	0.0	2463.6	0	1.000	5114.	1.146	0.687	11278.	0.0112	0.071
640.0	10794.	----	----	0.	5114.	----	A			0.0	0.687	0.00014	0.00109	0.0093

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.0	0.0	0.0	74227.	0.
0.0	0.0	0.0	74227.	5000.

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LB.)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TALK/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	RCTLIM CODE	J	C	CT	CLW	CDW	RN
0.0	0.0	0.0	74227.	5000.	181.0	2352.3	0	1.000	168.0	0.477	0.067	-3.0	.03822	11409.
640.0	10921.	----	----	----	4735.	----	----	0.0	----	----	----	----		----
0.000619	0.000222	0.000445	0.000071	0.02016	0.00377	0.00590	0.000560	A	----	----	----	----	----	----
0.02[illegible]	5.00	130.8	74097.	5000.	181.0	2352.3	0	1.000	168.0	0.477	0.067	-3.0	.03824	11407.
640.0	10920.	----	----	----	4734.	----	----	0.0	----	----	----	----		----
0.000619	0.000221	0.000446	0.000071	0.02015	0.00375	0.00590	0.000562	A	----	----	----	----	----	----

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

```
MISSION FUEL REQUIRED =   130.82
RESERVE FUEL REQUIRED =     0.0
TOTAL   FUEL REQUIRED =   130.82
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5674
-5.4

16

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END OF SUCCESSFUL CASE

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+5 PNdB HELI

TABLE 3.2. -5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674
+5H (8)

H E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM 8-91

MISSION PERFORMANCE DATA

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PEHF	AUX. ENG. FUEL FLOW (LBS/HR)
0.0	0.0	0.0	65843.	0.	0.0	1725.0	T	0.0	703.	----	----	----	
0.017	0.0	11.7	65832.	0.	0.0	1725.0	T	0.0	703.	----	----	----	

TAKEOFF, HOVER, OR LAND AT T/W = 1.140 FOR 0.033 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR EHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELDCM	FMI	CPPRO	CPIND	CDO
0.017	0.0	11.7	65832.	0.	0.0	2456.3	P	0.988	4038.	1.140	0.767	8921.	0.0070	0.100
810.0	8508.	----	----	0.	4038.		A			0.0016	0.767	0.00007	0.00046	0.0113
0.025	0.0	45.6	65798.	0.	0.0	2455.8	P	0.987	4036.	1.140	0.767	8914.	0.0070	0.100
810.0	8501.	----	----	0.	4036.		A			0.0015	0.767	0.00007	0.00046	0.0113
0.033	0.0	79.5	65764.	0.	0.0	2455.3	P	0.986	4033.	1.140	0.767	8907.	0.0070	0.099
810.0	8494.	----	----	0.	4033.		A			0.0015	0.767	0.00007	0.00046	0.0113
0.042	0.0	113.4	65730.	0.	0.0	2454.9	P	0.985	4031.	1.140	0.767	8900.	0.0070	0.099
810.0	8488.	----	----	0.	4031.		A			0.0015	0.767	0.00007	0.00046	0.0113

CLIMB TO 5000. FT. WITH MAXIMUM R/C AT MILITARY ENGINE RATING
** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH SPEED

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/C (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST	

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY.

ORIGINAL PAGE IS OF POOR QUALITY

D210-10858-2

5674 +5H (5)

CPPRC	CPIND	CPPAR	CPNUD	CDO	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN	
0.042	0.0	113.4	65730.	0.	80.6	2324.2	C	1.000	80.6	0.170	0.083	-0.7	10.2	5529.	1483.
810.0	5218.	----	----	----	3959.	----	----	0.0	----	----	----	----		----	
0.000120	0.000174	0.000013	0.000004	0.01606	0.00006	0.00555	0.000075	A	----	----	----	----	----	----	
0.053	0.92	157.9	65685.	1000.	80.6	2339.4	C	1.000	79.5	0.170	0.085	-0.7	9.9	5609.	1451.
810.0	5296.	----	----	----	3953.	----	----	0.0	----	----	----	----		----	
0.000123	0.000185	0.000013	0.000004	0.01655	0.00008	0.00602	0.000075	A	----	----	----	----	----	----	
0.065	1.86	203.3	65640.	2000.	8 .6	2347.3	C	1.000	79.3	0.172	0.088	-0.7	9.6	5697.	1415.
810.0	5381.	----	----	----	3918.	----	----	0.0	----	----	----	----		----	
0.000129	0.000193	0.000013	0.000004	0.01727	0.00011	0.00671	0.000077	A	----	----	----	----	----	----	
0.076	2.83	249.4	65594.	3000.	81.6	2356.0	C	1.000	78.1	0.172	0.090	-0.7	9.3	5789.	1377.
810.0	5473.	----	----	----	3885.	----	----	0.0	----	----	----	----		----	
0.000133	0.000205	0.000013	0.000004	0.01787	0.00015	0.00727	0.000077	A	----	----	----	----	----	----	
0.088	3.83	296.5	65547.	4000.	81.6	2365.7	C	1.000	76.9	0.172	0.093	-0.7	9.1	5888.	1335.
810.0	5566.	----	----	----	3856.	----	----	0.0	----	----	----	----		----	
0.000138	0.000217	0.000013	0.000004	0.01851	0.00019	0.00787	0.000077	A	----	----	----	----	----	----	
0.101	4.86	344.6	65499.	5000.	82.6	2376.6	C	1.000	76.7	0.174	0.096	-0.7	8.7	5995.	1291.
810.0	5670.	----	----	----	3828.	----	----	0.0	----	----	----	----		----	
0.000146	0.000228	0.000014	0.000005	0.01944	0.00026	0.00873	0.000078	A	----	----	----	----	----	----	

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	ML	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RMP	T.ROTOR VTIP (FPS)	T.ROTOR RMP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
0.101	4.86	344.6	65499.	5000.	142.1	2362.5	Q	1.000	131.9	0.296	0.095	-1.9	.03748	9039.
810.0	8623.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000367	0.000136	0.000074	0.000019	0.03973	0.00179	0.027	0.000226	A	----	----	----	----	----	----
0.171	14.86	611.4	65232.	5000.	142.4	2362.5	Q	1.000	132.2	0.297	0.095	-2.0	.03757	9039.
810.0	8622.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000368	0.000135	0.000074	0.000019	0.03977	0.00176	0.02751	0.000227	A	----	----	----	----	----	----
0.242	24.86	877.6	64966.	5000.	142.7	2362.4	C	1.000	132.5	0.297	0.094	-2.0	.03765	9038.
810.0	8622.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000369	0.000133	0.000075	0.000019	0.03980	0.00174	0.02757	0.000228	A	----	----	----	----	----	----
0.312	34.86	1143.2	64700.	5000.	143.0	2362.3	C	1.000	132.7	0.298	0.094	-2.0	.03773	9038.

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674 15H 10

810.0	8621.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000369	0.000132	0.000075	0.000019	0.03984	0.00172	0.02762	0.000229	A	----	----	----	----	----	----
0.382	44.86	1438.2	64435.	5000.	143.3	2362.2	C	1.000	133.0	0.299	0.094	-2.0	.03782	9038.
810.0	8621.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000370	0.000131	0.000076	0.000019	0.03987	0.00170	0.02768	0.000230	A	----	----	----	----	----	----
0.451	54.86	1672.6	64171.	5000.	143.6	2362.1	C	1.000	133.3	0.299	0.093	-2.0	.03790	9037.
810.0	8621.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000371	0.000129	0.000076	0.000019	0.03990	0.00168	0.02773	0.000231	A	----	----	----	----	----	----
0.521	64.86	1936.5	63907.	5000.	143.9	2362.1	C	1.000	133.6	0.300	0.093	-2.0	.03798	9037.
810.0	8620.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000372	0.000128	0.000077	0.000019	0.03993	0.00165	0.02778	0.000232	A	----	----	----	----	----	----
0.593	74.86	2199.8	63643.	5000.	144.2	2362.0	C	1.000	133.9	0.301	0.093	-2.1	.03806	9037.
810.0	8620.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000372	0.000127	0.000077	0.000019	0.03996	0.00163	0.02783	0.000233	A	----	----	----	----	----	----
0.660	84.86	2462.5	63381.	5000.	144.5	2361.9	C	1.000	134.2	0.301	0.092	-2.1	.03814	9036.
810.0	8620.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000373	0.000125	0.000078	0.000019	0.03999	0.00161	0.02788	0.000234	A	----	----	----	----	----	----
0.729	94.86	2724.7	63118.	5000.	144.8	2361.8	C	1.000	134.4	0.302	0.092	-2.1	.03822	9036.
810.0	8619.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000374	0.000124	0.000079	0.000019	0.04002	0.00159	0.02793	0.000235	A	----	----	----	----	----	----
0.798	104.86	2986.4	62857.	5000.	145.1	2361.8	C	1.000	134.7	0.302	0.091	-2.1	.03830	9036.
810.0	8619.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000375	0.000123	0.000079	0.000019	0.04004	0.00157	0.02798	0.000236	A	----	----	----	----	----	----
0.867	114.86	3247.5	62596.	5000.	145.4	2361.7	C	1.000	135.0	0.303	0.091	-2.1	.03838	9036.
810.0	8619.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000375	0.000121	0.000080	0.000019	0.04007	0.00155	0.02803	0.000237	A	----	----	----	----	----	----
0.936	124.86	3508.1	62335.	5000.	145.7	2361.6	C	1.000	135.2	0.304	0.091	-2.2	.03845	9035.
810.0	8619.	----	----	----	3789.	----	----	0.0	----	----	----	----		----
0.000376	0.000120	0.000080	0.000019	0.04010	0.00153	0.02808	0.000238	A	----	----	----	----	----	----
1.004	134.86	3768.1	62075.	5000.	146.0	2361.6	C	1.000	135.5	0.304	0.090	-2.2	.03853	9035.
810.0	8619.	----	----	----	3788.	----	----	0.0	----	----	----	----		----
0.000377	0.000119	0.000081	0.000019	0.04012	0.00150	0.02812	0.000239	A	----	----	----	----	----	----
1.073	144.86	4027.7	61816.	5000.	147.0	2361.3	C	1.000	136.5	0.306	0.090	-2.2	.03881	9121.
810.0	8701.	----	----	----	3788.	----	----	0.0	----	----	----	----		----
0.000382	0.000117	0.000083	0.000019	0.04052	0.00152	0.02851	0.000242	A	----	----	----	----	----	----
1.141	154.86	4285.3	61558.	5000.	147.3	2361.2	C	1.000	136.7	0.307	0.090	-2.2	.03888	9118.
810.0	8699.	----	----	----	3788.	----	----	0.0	----	----	----	----		----
0.000382	0.000116	0.000083	0.000019	0.04053	0.00150	0.02854	0.000243	A	----	----	----	----	----	----
1.209	164.86	4542.6	61301.	5000.	147.5	2361.2	C	1.000	136.9	0.307	0.089	-2.2	.03895	9116.
810.0	8697.	----	----	----	3788.	----	----	0.0	----	----	----	----		----
0.000383	0.000115	0.000084	0.000019	0.04054	0.00147	0.02858	0.000244	A	----	----	----	----	----	----
1.277	174.86	4799.3	61044.	5000.	147.8	2361.1	C	1.000	137.2	0.308	0.089	-2.3	.03901	9114.
810.0	8695.	----	----	----	3788.	----	----	0.0	----	----	----	----		----
0.000384	0.000114	0.000084	0.000019	0.04056	0.00145	0.02861	0.000245	A	----	----	----	----	----	----
1.344	184.86	5055.6	60788.	5000.	148.0	2361.0	C	1.000	137.4	0.308	0.088	-2.3	.03908	9112.

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674 +54 (11)

810.0	8693.	---	----	----	3787.	----	----	0.0	----	----	----	----			----
0.000384	0.000113	0.000085	0.000019	0.04057	0.00143	0.02864	0.000246	A	----	----	----	----	----		----
1.412	194.86	5311.5	60532.	5000.	148.3	2361.0	Q	1.000	137.6	0.309	[illegible]	-2.3	.03915		9109.
810.0	9691.	----	----	----	3787.	----	----	0.0	----	----	----	----			----
0.000385	0.000111	0.000095	0.000019	0.04056	0.00141	0.02867	0.000247	A	----	----	----	----	----		----
1.434	198.20	5396.7	604[illegible]	5000.	148.4	2360.9	Q	1.000	137.7	0.309	0.088	-2.3	.03917		9109.
810.0	[illegible]	----	----	----	3787.	----	----	0.0	----	----	----	----			----
0.000385	0.000111	0.000095	0.0000[illegible]	0.04058	0.00140	0.02869	0.000247	A	----	----	----	----	----		----

DESCEND TO H = 2000. FT. ,R = [illegible]0.00 N.MI. AT CONSTANT TAS

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/S (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST	
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN	
1.434	198.20	5396.7	60446.	5000.	115.0	1740.0	T	0.783	106.8	0.240	0.085	14.0	-15.3	-0.	3078.
810.0	-146.	----	----	----	1150.	----	----	0.0	----	----	----	----		----	
0.003216	0.000133	-.000369	0.000010	0.02601	0.00001	0.01551	-.001476	A	----	----	----	----	----	----	
1.440	199.80	5402.9	60440.	4000.	115.0	1740.0	T	0.783	106.8	0.240	0.085	14.0	-15.3	0.	3078.
810.0	-145.	----	----	----	1150.	----	----	0.0	----	----	----	----		----	
0.003216	0.000133	-.000369	0.000010	0.02601	0.00001	0.01551	-.001476	A	----	----	----	----	----	----	
1.445	199.40	5409.1	60434.	3000.	115.0	1740.0	T	0.783	106.8	0.240	0.085	14.0	-15.3	0.	3078.
810.0	-145.	----	----	----	1150.	----	----	0.0	----	----	----	----		----	
0.003216	0.000133	-.000369	0.000010	0.02601	0.00001	0.01551	-.001475	A	----	----	----	----	----	----	
1.451	200.00	5415.4	60428.	2000.	115.0	1740.0	T	0.783	106.8	0.240	0.085	14.0	-15.3	0.	3078.
810.0	-145.	----	----	----	1150.	----	----	0.0	----	----	----	----		----	
0.003216	0.000133	-.000368	0.000010	0.02600	0.00001	0.01550	-.001475	A	----	----	----	----	----	----	

LOITER FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	TOTAL FUEL FLOW (LBS/HR)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCOS	DELCOM	CXR	RCTLIM	J	CP	CT	CLW	CDW	RN

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY, (CONTINUED)

CODE

5674
+54

(12)

1.451	200.00	5415.4	60428.	2000.	80.6	2098.6	P	0.568	78.3	0.168	0.081	-0.7	2668.		5128.
810.0	4829.		----	----	2668.	----	----	0.0	----	----	----	----			----
0.000121	0.000168	0.000012	0.000003	0.01631	0.00004	0.00582	0.000073	A	----	----	----	----	----		----
1.476	200.00	5482.1	60361.	2000.	80.6	2098.1	P	0.567	78.3	0.168	0.081	-0.7	2666.		5122.
810.0	4522.		----	----	2666.	----	----	0.0	----	----	----	----			----
0.000121	0.000168	0.000012	0.000003	0.01630	0.00004	0.00581	0.000073	A	----	----	----	----	----		----

DESCEND TO H = 1000. FT. AT CONSTANT TAS (SPIRAL DESCENT PATH - NO RANGE CREDIT)

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/S (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PRCP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST	
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN	
1.476	200.00	5482.1	60361.	2000.	70.0	1974.8	P	0.355	68.0	0.146	0.080	7.5	-8.1	3206.	1000.
310.0	2965.		----	----	2099.	----	----	0.0	----	----	----	----		----	
0.000106	0.000187	-.000106	0.000002	0.01463	0.00000	0.00422	-.000736	A	----	----	----	----	----	----	
1.484	200.58	5499.6	60344.	1500.	70.0	1974.7	P	0.355	68.0	0.146	0.080	7.5	-8.1	3205.	1000.
310.0	2963.		----	----	2099.	----	----	0.0	----	----	----	----		----	
0.000106	0.000187	-.000108	0.000002	0.01463	0.00000	0.00421	-.000736	A	----	----	----	----	----	----	
1.492	201.16	5517.0	60326.	1000.	70.0	1974.6	P	0.355	68.0	0.146	0.080	7.5	-8.1	3203.	1000.
310.0	2962.		----	----	2098.	----	----	0.0	----	----	----	----		----	
0.000105	0.000187	-.000108	0.000002	0.01463	0.00000	0.00421	-.000736	A	----	----	----	----	----	----	

TRANSFER ALTITUDE TO 0. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.492	200.00	5517.0	60326.	1000.
1.492	200.00	5517.0	60326.	0.

TAKEOFF, HOVER, OR LAND AT T/W = 1.140 FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	RCTLIM CODE			DELOCM	FMI	CPPRO	CPIND	CDO

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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5L74 +5.4 (13)

1.492	200.00	5517.0	60326.	0.	0.0	2384.6	P	0.865	3666.	1.140	0.770	7816.	0.0064	0.091
810.0	7430.	----	----	0.	3666.	----	A			0.0008	0.770	0.00007	0.00040	0.0104
1.501	200.00	5547.8	60295.	0.	0.0	2384.3	P	0.865	3664.	1.140	0.770	7810.	0.0064	0.091
810.0	7431.	----	----	0.	3664.	----	A			0.0008	0.770	0.00007	0.00040	0.0104
1.509	200.00	5578.6	60265.	0.	0.0	2383.9	P	0.864	3662.	1.140	0.770	7804.	0.0064	0.091
810.0	7425.	----	----	0.	3662.	----	A			0.0008	0.770	0.00007	0.00040	0.0104

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PEHF	AUX. ENG. FUEL FLOW (LBS/HR)
1.509	200.00	5578.6	60265.	0.	0.0	1725.0	T	0.0	703.	----	----	----	----
1.526	200.00	5590.3	60253.	0.	0.0	1725.0	T	0.0	703.	----	----	----	----

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.526	200.00	5590.3	60253.	0.
1.526	200.00	5590.3	60253.	5000.

CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF 0.0 KNOTS FOR RESERVEFUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TAUX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPROJ	CPIND	CPPAR	CPWUD	CDO	DELCDS	DELCOM	CXR	RCTLIM CODE	J	CF	CT	CLW	CDW	RN
1.526	200.00	5590.3	60253.	5000.	140.0	2300.7	P	0.906	129.9	0.292	0.088	-2.1	.04000	8180.
810.0	7789.	----	----	----	3593.	----	----	0.0	----	----	----	----		----
0.000334	0.000117	0.000070	0.000017	0.03651	0.00106	0.02496	0.000220	A	----	----	----	----	----	----
1.597	210.00	5840.3	60003.	5000.	139.5	2295.1	P	0.897	129.4	0.291	0.087	-2.0	.04014	8102.
810.0	7714.	----	----	----	3477.	----	----	0.0	----	----	----	----		----
0.000331	0.000116	0.000069	0.000017	0.03619	0.00101	0.02468	0.000218	A	----	----	----	----	----	----
1.669	220.00	6089.4	59754.	5000.	139.5	2293.1	P	0.894	129.4	0.291	0.087	-2.1	.04025	8074.
810.0	7666.	----	----	----	3468.	----	----	0.0	----	----	----	----		----
0.000330	0.000115	0.000065	0.000016	0.03609	0.00099	0.02461	0.000218	A	----	----	----	----	----	----
1.741	230.00	6337.9	59505.	5000.	139.5	2291.0	P	0.891	129.4	0.291	0.087	-2.1	.04036	8046.

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

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810.3	7659.	----	----	----	3458.	----	----	0.0	----	----	----	----		----
0.000329	0.000114	0.000069	0.000016	0.03600	0.00097	0.02454	0.000218	A	----	----	----	----	----	----
1.812	240.00	6585.6	59257.	5000.	139.5	2289.0	P	0.888	129.4	0.291	0.086	-2.1	.04047	8017.
810.0	7631.	----	----	----	3449.	----	----	0.0	----	----	----	----		----
0.000328	0.000113	0.000069	0.000016	0.03590	0.00094	0.02447	0.000218	A	----	----	----	----	----	----
1.834	250.00	6832.7	59010.	5000.	139.5	2287.0	P	0.885	129.4	0.291	0.086	-2.1	.04058	7990.
810.0	7604.	----	----	----	3440.	----	----	0.0	----	----	----	----		----
0.000327	0.000113	0.000069	0.000016	0.03581	0.00092	0.02440	0.000218	A	----	----	----	----	----	----

LOITER FOR 0.333 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEMF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	TOTAL FUEL FLOW (LBS/HR)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	TALX/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEMF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
1.526	250.00	6832.7	60253.	5000.	81.5	2112.9	P	0.594	75.6	0.170	0.088	-0.7	2629.	5363.
810.0	5056.	----	----	----	2629.	----	----	0.0	----	----	----	----		----
0.000135	0.000193	0.000013	0.000004	0.01812	0.00011	0.00756	0.000074	A	----	----	----	----	----	----
1.626	250.00	7095.6	59990.	5000.	81.5	2110.8	P	0.591	75.6	0.170	0.088	-0.7	2619.	5332.
810.0	5027.	----	----	----	2619.	----	----	0.0	----	----	----	----		----
0.000135	0.000196	0.000013	0.000004	0.01809	0.00011	0.00753	0.000074	A	----	----	----	----	----	----
1.726	250.00	7357.6	59728.	5000.	81.5	2108.8	P	0.587	75.6	0.170	0.087	-0.7	2610.	5303.
810.0	4998.	----	----	----	2610.	----	----	0.0	----	----	----	----		----
0.000134	0.000194	0.000013	0.000004	0.01805	0.00010	0.00750	0.000074	A	----	----	----	----	----	----
1.826	250.00	7618.6	59467.	5000.	81.5	2106.8	P	0.584	75.6	0.170	0.087	-0.7	2601.	5273.
810.0	4969.	----	----	----	2601.	----	----	0.0	----	----	----	----		----
0.000134	0.000193	0.000013	0.000004	0.01801	0.00010	0.00746	0.000074	A	----	----	----	----	----	----
1.859	250.00	7704.4	59381.	5000.	81.5	2106.1	P	0.583	75.6	0.170	0.087	-0.7	2598.	5263.
810.0	4960.	----	----	----	2598.	----	----	0.0	----	----	----	----		----
0.000134	0.000192	0.000013	0.000004	0.01800	0.00010	0.00745	0.000074	A	----	----	----	----	----	----

MISSION FUEL REQUIRED = 5590.29
RESERVE FUEL REQUIRED = 2114.08
TOTAL FUEL REQUIRED = 7704.38

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

CASE 2 5 PNDB PAGE 8 5674 +5H 15

HESCOMP
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM 8-91

MISSION PERFORMANCE DATA

TAKEOFF, HOVER, OR LAND AT PETF = 1.000 FOR 0.001 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	ROTLIM CODE			DELDCM	FMI	CPPRO	CPIND	CDD
0.0	0.0	0.0	65843.	0.	0.0	2463.6	Q	1.000	4076.	1.144	0.767	8973.	0.0070	0.100
810.0	8558.	----	----	0.	4076.	----	A			0.0016	0.767	0.00007	0.00047	0.0114

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.0	0.0	0.0	65843.	0.
0.0	0.0	0.0	65843.	5000.

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	PRIM. ENG. PEHF	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	SHP AUX	ETAP PRCP	TALK/T	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEHF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDD	DELCOS	DELCOM	CXR	RCTLIM CODE	J	CP	CT	CLW	CDW	RN
0.0	0.0	0.0	65843.	5000.	141.7	2362.6	Q	1.000	131.5	0.295	0.096	-1.9	.03737	9040.
813.0	8623.	----	----	----	3791.	----	----	0.0	----	----	----	----		----
0.000366	0.000138	0.000073	0.000019	0.03969	0.00181	0.02738	0.000225	A	----	----	----	----	----	----
0.035	5.00	133.8	65710.	5000.	141.8	2362.6	Q	1.000	131.6	0.296	0.096	-1.9	.03741	9039.
810.0	8623.	----	----	----	3790.	----	----	0.0	----	----	----	----		----
0.000366	0.000137	0.000073	0.000019	0.03970	0.00180	0.02741	0.000226	A	----	----	----	----	----	----

TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

5674
+5H

16

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MISSION FUEL REQUIRED =   133.80
RESERVE FUEL REQUIRED =     0.0
TOTAL   FUEL REQUIRED =   133.80

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END OF SUCCESSFUL CASE

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TABLE 3.3. +5 PNdB DERIVATIVE HELICOPTER MISSION TIME HISTORY. (CONTINUED)

portion of the fuselage between the rotors into components having similar airframe cross sections. Each component is analyzed separately to obtain the local download. The fuselage download is then the sum of the component. The download can be written -

$$\left.\frac{DL}{T}\right]_{\%R_1}^{\%R_2} = \frac{C_D\ \omega}{800\ \pi\ R}\left[K_{DL}\right]_{\%R_1}^{\%R_2}$$

where

DL = local downlaod

T = thrust

C_D = local vertical drag coefficient

W = local fuselage width

R = rotor radius

$$K_{DL} = \sum_{0}^{\%R}\left(\frac{v}{v_o}\right)^2 d\ (\%R)$$

v = downwash velocity

v_o = momentum theory induced velocity

%R = distance aft from forward rotor in percent radius

The vertical drag coefficients for the fuselage cross sections were obtained from statistical trends as shown in Figure 3.1. The downwash velocity squared distribution K_{DL} was determined using pressure distribution data from a powered model in the Boeing Vertol V/STOL Wind Tunnel (BV D210-10077). Typical

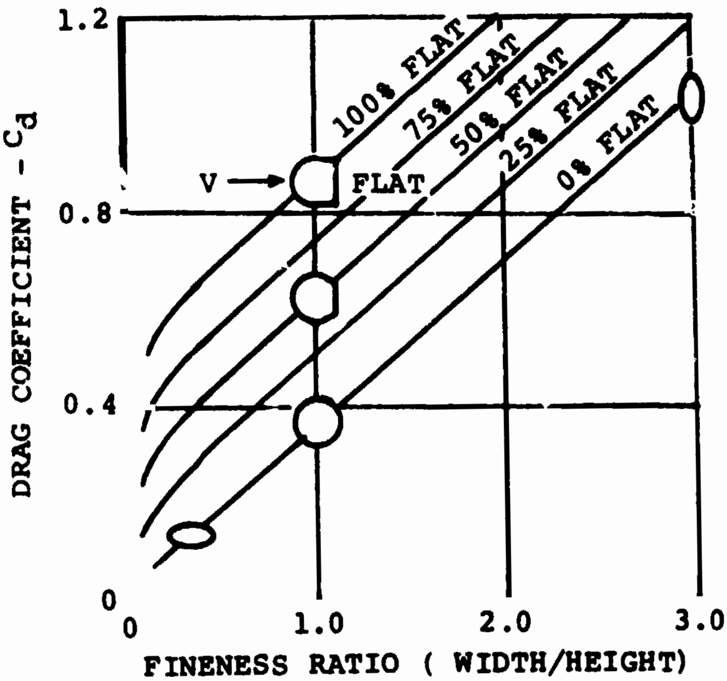


FIGURE 3.1 DETERMINATION OF VERTICAL DRAG COEFFICIENT.

downwash velocity distribution for several rotor overlap ratios are shown in Figure 3.2. This download analysis was applied to an initial matrix of helicopters involving the variables NOP (Number of Passengers) and disc loading. The downloads are summarized in Figure 3.3 to the lines of constant NOP. The fuselage shape is essentially fixed. The variation in disc loading implies a variation for rotor overlap. The download variations with overlap and NOP are shown in Figure 3.4.

This analysis was also applied to the design point helicopter. The download for this aircraft was estimated to 8.6% of the thrust. The results are listed below.

TANDEM HELICOPTER DOWNLOAD							
FUSELAGE	%R	$v^K{}_{DL}$	W(Ft)	FINENESS RATIO	% FLAT	C_D	DL
Forward	0-100	290	14.67	1.56	70	.91	.045
Aft	100-200	290	14.67	1.33	70	.84	.041
				TOTAL			.086

Rotor Performance - Tandem Helicopters

The HESCOMP computer program includes a routine which computes the performance of the specified rotor using a series of generalized semi-empirical equations. These equations have been used to define the rotor performance in hover and cruise flight. A summary of the method is given in Tables 3.4 and 3.5.

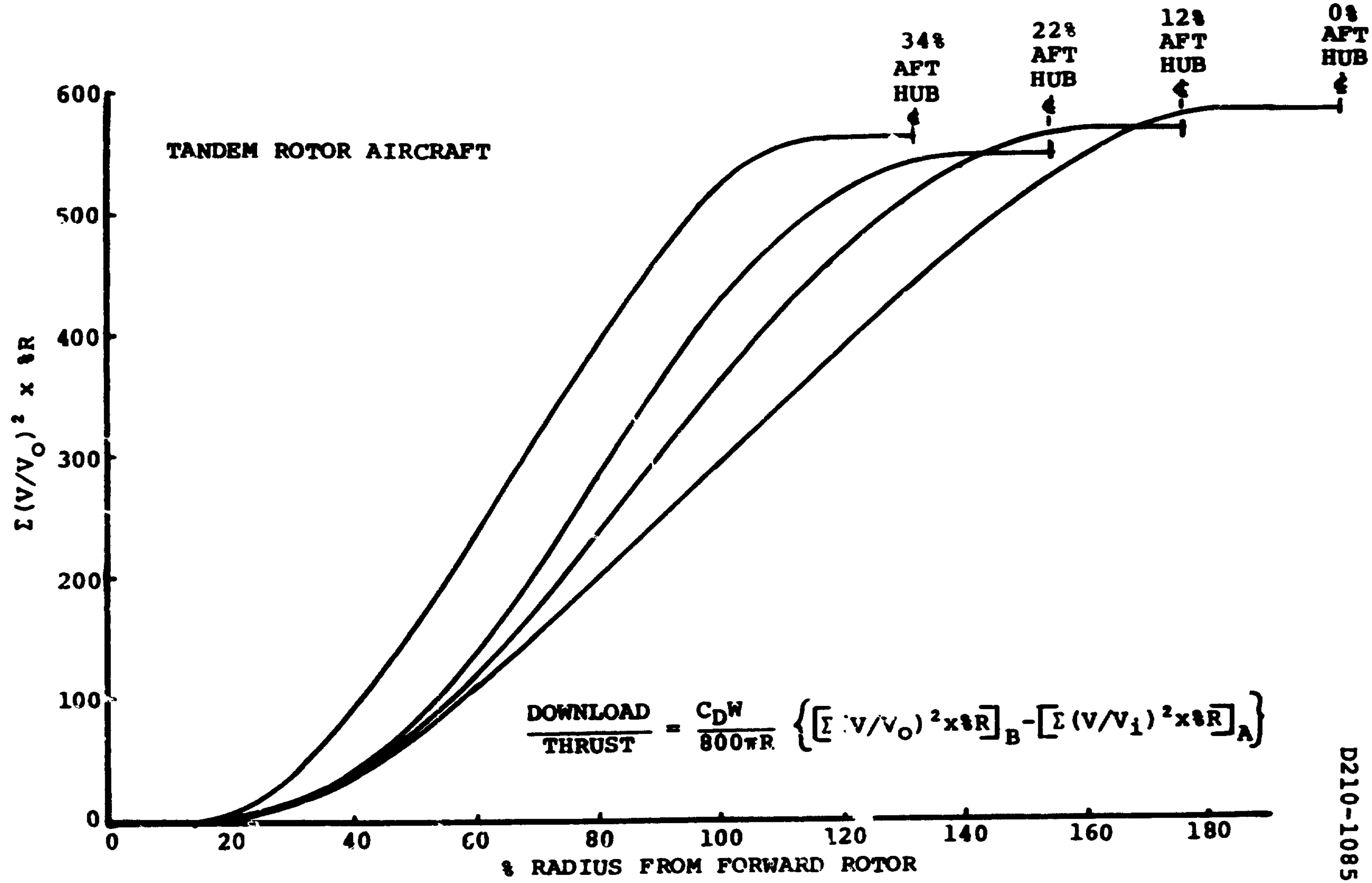


FIGURE 3.2. INTEGRATED NON-DIMENSIONAL DOWNWASH VELOCITY

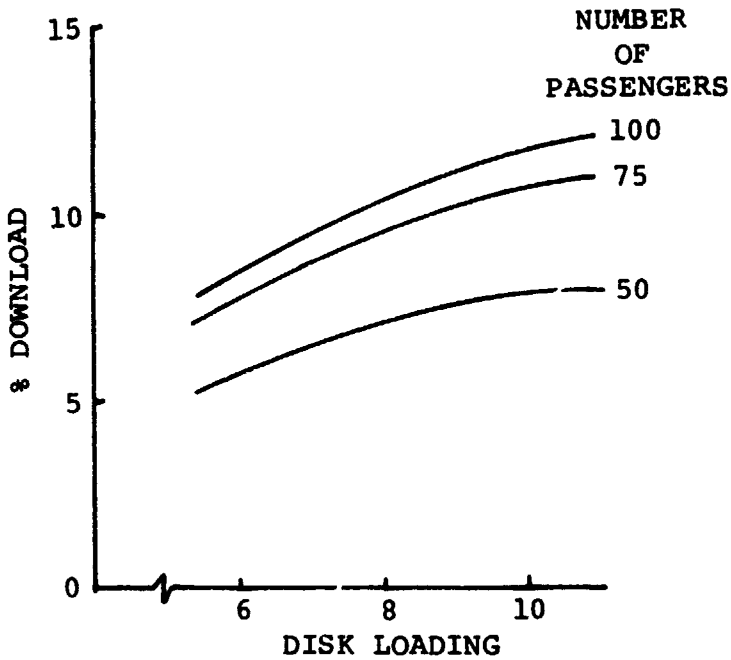


FIGURE 3.3. EFFECT OF DISC LOADING ON TANDEM HELICOPTER DOWNLOAD.

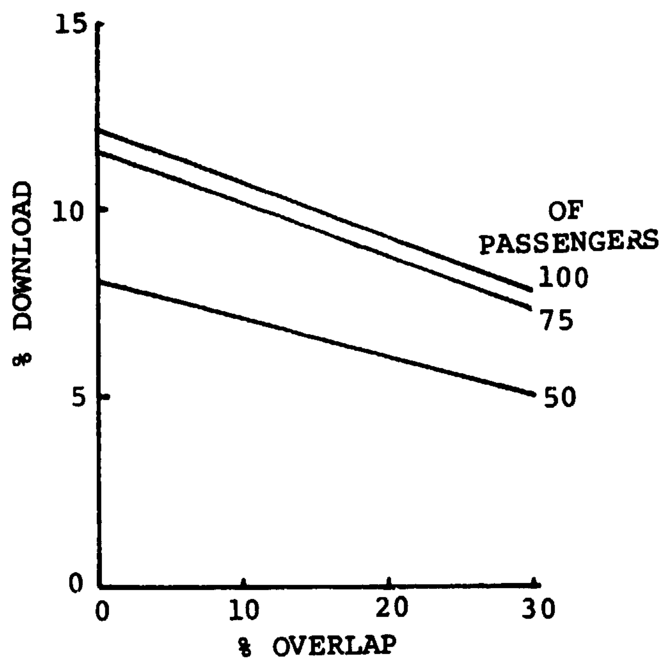


FIGURE 3.4. EFFECT OF OVERLAP ON TANDEM HELICOPTER DOWNLOAD.

This methodology has been checked against known rotors and provides good correlation against wind tunnel and flight test data as shown in Figure 3.5.

The rotor solidity was sized by maneuver conditions (see Section 3.5) and the rotor twist was examined to determine the best rotor for these aircraft.

The impact of varying rotor twist on aircraft size and performance is shown in Figure 3.6. Increasing the blade twist improves the aircraft capability. The blade twist was selected at 12 degrees since experience with rotor loads and stresses at higher twist suggests that risk would be involved. The rotor twist selected for HLH and UTTAS is 12 degrees for similar reasons.

The drag methodology used to derive the parasite drag is described in Reference 3 . This method is shown diagramatically in Figure 3.7. The approach uses a semi-empirical technique to establish the component contribution and mutual interference effects to arrive at an estimate of the total parasite drag area of the vehicle. Rotor hub drag was derived from HLH rotor test data defined in Reference and scaled as aircraft size for this study. The component drag estimate for the baseline helicopter is given in Table 3.6. This was utilized as a gross weight to drag area ratio to develop the trend curve used in the trend studies and is shown in Figure 3.8.

MAIN ROTOR IN HOVER

SUMMARY

$$RHP_{TOT} = \frac{\rho A V_T{}^3 C_{P_{TOT}}}{550}$$

where:

$$C_{P_{TOT}} = C_{P_{PRO}} + C_{P_{IND}}$$

$$C_{P_{PRO}} = C_{D_O} \frac{\sigma}{8} \quad (1-X_c)$$

$$C_{P_{IND}} = .707 K_{HOV} K_{OL} C_T{}^{3/2}$$

$$C_T = \frac{\text{HOVER THRUST REQ'D}}{\rho A V_T{}^2}$$

$$A = \frac{\pi D^2}{4} N_{ROT}$$

$$X_c = 2r_{cutout}/D$$

TABLE 3.4. HOVER ROTOR PERFORMANCE TANDEM HELICOPTER.

TABLE 3.4. HOVER ROTOR PERFORMANCE TANDEM HELICOPTER. (CONTINUED)

MAIN ROTOR INHOVER INDUCED POWER

$$C_{P_{IND}} = .707 K_{HOV} K_{OL}\ C_T^{3/2}$$

$$C_T = \frac{\text{HOVER THRUST REQUIRED}}{\rho A V_T^{2}}$$

$$A = \frac{\pi D^2}{4} \cdot N_{ROT}$$

K_{HOV} = Hover induced power factor (K_{HOV} = f (C_T, blade NO., blade TWIST)

K_{OL} = Tandem rotor overlap induced power interference factor (K_{OL} = f (O/L))

where:

$$K_{HOV} = [K_{HOV_A} + \Delta K_{HOV_{\theta_T}} - \Delta K_{HOV_{\theta_{T_{REF}}}} - 1] K_{BLH} + 1$$

θ_T →	0°	-3°	-6°	-9°	-15°
C_T	$\Delta K_{HOV_{\theta_T}}$	$\Delta K_{HOV_{\theta_T}}$	$\Delta K_{HOV_{\theta_T}}$	$\Delta K_{HOV_{\theta_T}}$	$\Delta K_{HOV_{\theta_T}}$
.004	0.	-.078	-.135	-.179	-.219
.005	0.	-.066	-.118	-.159	-.204
.006	0.	-.058	-.106	-.145	-.195
.007	0.	-.052	-.097	-.134	-.186
.008	0.	-.048	-.090	-.125	-.179
.010	0.	-.041	-.078	-.111	-.164
.012	0.	-.035	-.069	-.100	-.152
.014	0.	-.033	-.063	-.093	-.144
.018	0.	-.029	-.058	-.084	-.132
.022	0.	-.028	-.054	-.080	-.124

BLADE NO.	K_{BLH}*
2	1.20
3	1.06
4	1.00
5	.955
6	.92

* IN THIS CASE K_{BLH} Ref'd to b=4

$$K_{OL} = 1 + .75 (O/L)^{5/3}$$

MAIN ROTOR IN HOVER

PROFILE POWER

$$C_{P_{PRO}} = C_{D_O}\frac{\sigma}{8}(1-X_C)$$

where:

$$C_{D_O} = C_{D_B} + \Delta C_{D_M}$$

$$C_{D_B} = C_{D_{B_O}} + K_{H_1}(C_T/\sigma) + K_{H_2}(C_T/\sigma)^2$$

$$\Delta C_{D_M} = K_{H_3}(M_T - M_D)^2$$

$$M_D = M_{D_B} - K_{H4}(C_T/\sigma)$$

$$M_{D_B} = M_{D_{B_O}} + \Delta M_{D_{B_B}} + K_{M_{D_B}}(\theta_T - \theta_{T_{REF}})$$

where:

BLADE NO.	$\Delta M_{D_{B_B}}$*
2	.020
3	.0075
4	0
5	-.005
6	-.0085

* in this case $\Delta M_{D_{B_B}}$ ref'd to b=4

$$K_{M_{D_B}} = -.0028$$

$$\left.\begin{array}{l} C_{D_{B_O}} \\ M_{D_{B_O}} \\ K_{H_1}, K_{H_2}, K_{H_3}, K_{H_4} \end{array}\right\} = f \text{ (rotor blade airfoil section)}$$

TABLE 3.4. HOVER ROTOR PERFORMANCE TANDEM HELICOPTER. (CONTINUED)

MAIN ROTOR IN CRUISE FLIGHT
SUMMARY

$$RHP_{TOT} = \frac{\rho A V_T{}^3 C_P}{550}{}_{TOT}$$

where:

$$C_{P_{TOT}} = C_{P_{PRO}} + C_{P_{IND}} + C_{P_{PAR}} + C_{P_{NUD}}$$

$$C_{P_{PRO}} = \frac{C_{D_O}\sigma}{8}(1+4.65\mu^2)(1-X_C)$$

$$C_{P_{IND}} = \frac{K_{IND}K_{INT}}{2\mu'} C_T'^2$$

$$C_{P_{PAR}} = \mu C_X (K_{PER})$$

$$C_{P_{NUD}} = \frac{2K_{NUD}C_T'\sigma}{B^2(1+D.L.\sin^2\epsilon)}$$

$$C_T' = \frac{L_{ROT}(1+D.L.\sin^2\epsilon)}{\rho A V_T{}^2}$$

$$C_X = \frac{X_{TOT}}{\rho A V_T{}^2} \qquad A = \frac{\pi D^2}{4} N_{ROT}$$

$$\epsilon = \tan^{-1}(2V_i/V\text{x}1.689)$$

$$v_i = V_T\sqrt{[(\mu^4+C_T{}^2)^{1/2}-\mu^2]/2}$$

$$\mu' = \frac{\sqrt{(1.689V)^2+v_i{}^2}}{V_T}$$

$$K_{PER} = \frac{\eta_{PRI}}{\eta_{PRR}} = 1+12.8\mu^4$$

$$K_{NUD} = f(\mu)$$

TABLE 3.5. CRUISE ROTOR PERFORMANCE TANDEM HELICOPTER.

MAIN ROTOR IN CRUISE FLIGHT
INDUCED POWER

$$C_{P_{IND}} = \frac{K_{IND} K_{INT} C_T'^2}{2\mu'}$$

where:

$K_{IND} = 1.1 \cos^2\varepsilon + K'_{HOV} \sin^2\varepsilon$

$K_{INT} = [.375 \left((O/L)/_D\right)^{5/3}]\sin^2\varepsilon + K_{INT_O}$

$K'_{HOV} = K_{HOV}$ recalculated based on a C_T defined as:

$$C_T = \frac{GW(1+DL \sin^2\varepsilon)}{\rho A V_T^2}$$

K_{INT_O} = 1.00 for a single rotor helicopter

K_{INT_O} = f(ε') for a tandem rotor helicopter

where:

$$\varepsilon' = \sin^{-1}\left\{\left(1-(O/L)/D\right) \sin\left[-\tan^{-1}\left[\left(\frac{.043}{\mu+.043}\right)\left(\frac{v_i}{1.688V}\right)\right] + \alpha_{FUS} - \gamma_O\right]\right\}$$

α_{FUS} = Fuselage attitude

γ_O = Hub gap/stagger angle

ε'	K_{INT_O}
-90.	1.0
-50.5	1.032
-41.3	1.062
-29.75	1.139
-19.5	1.30
- 7.5	1.685
- 6.0	1.780
- 4.0	1.870
- 2.0	1.900
0.	1.880
4.	1.710
7.5	1.550
15.5	1.360
29.75	1.139
90.	1.000

MAIN ROTOR IN CRUISE FLIGHT
PROFILE POWER

$$C_{P_{PRO}} = \frac{C_{D_o}\,\sigma}{8}\,(1+4.65\mu^2)(1-X_C)$$

where:

$$C_{D_o} = C_{D_B}\cos^2\varepsilon + C_{D_B}'\sin^2\varepsilon + \Delta C_{D_S} + \Delta C_{D_M}$$

$$\Delta C_{D_S} = K_{C_1} F^3 \cos^2\varepsilon\,(1-\mu)^2$$

$$\Delta C_{D_M} = [K_{C_3}(M_{T_{90}}-M_D)^3 + K_{C_4}(M_{T_{90}}-M_D)]\cos^2\varepsilon + \Delta C_{D_M}'\sin^2\varepsilon$$

$$F = \left[\frac{C_T'/\sigma}{(1-\mu)^2}\right]\left[1+\frac{C_X}{C_T'}\right] - K_{C_2}$$

$$M_D = M_{D_o} - K_{C_5}\,(C_T'/\sigma)$$

$$M_{T_{90}} = M_\infty + M_{TIP}$$

where:

$C_{D_B}' = C_{D_B}$ (HOVER) recalculated based on a C_T defined as:

$$C_T = \frac{GW(1+DL\sin^2\varepsilon)}{\rho A V_T^2}$$

$\Delta C_{D_M}' = \Delta C_{D_M}$ (HOVER) recalculated based on a C_T defined as:

$$C_T = \frac{GW(1+DL\sin^2\varepsilon)}{\rho A V_T^2}$$

$$\left.\begin{array}{l} C_{D_B} \\ M_{D_o} \\ K_{C_1},\ K_{C_2},\ K_{C_3},\ K_{C_4},\ K_{C_5} \end{array}\right\} = f\text{(ROTOR blade airfoil section)}$$

TABLE 3.5 CRUISE ROTOR PERFORMANCE TANDEM HELICOPTER. (CONTINUED)

μ	K_{NUD}
0	0.
.05	0.
.125	.025
.2	.105
.25	.205
.325	.397
.36	.475
.37	.48
.386	.475
.4	.432
.425	.342
.45	.33
.475	.333
.525	.342
.55	.355
.6	.375
.7	.412
.8	.444
.9	.474
1.0	.5

TABLE 3.5. CRUISE ROTOR PERFORMANCE TANDEM HELICOPTER. (CONTINUED)

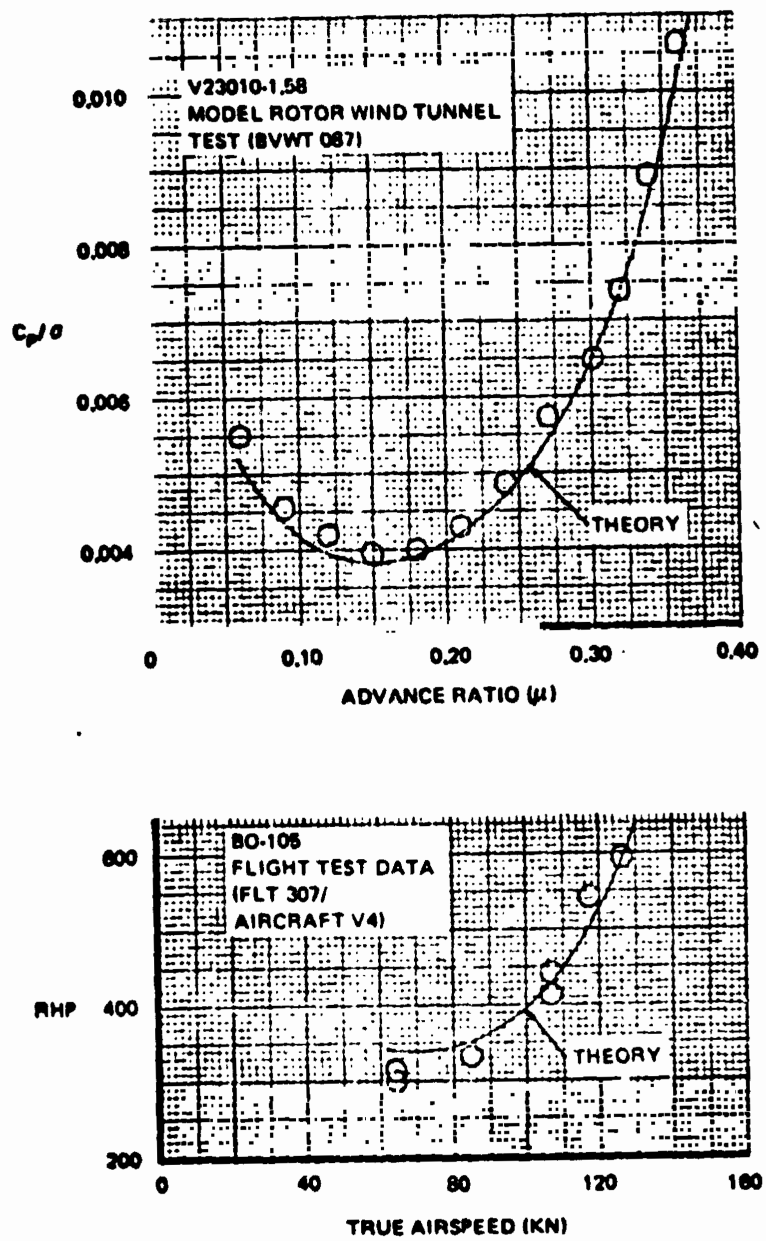


FIGURE 3.5. FLIGHT TEST AND WIND TUNNEL TEST RESULTS CONFIRM ROTOR PERFORMANCE PREDICTION METHODS.

100 PASSENGER HELICOPTER

EFFECT OF ROTOR BLADE TWIST ON AIRCRAFT SIZE

V_{TIP} = 725 FPS   W/A = 9.0 PSF

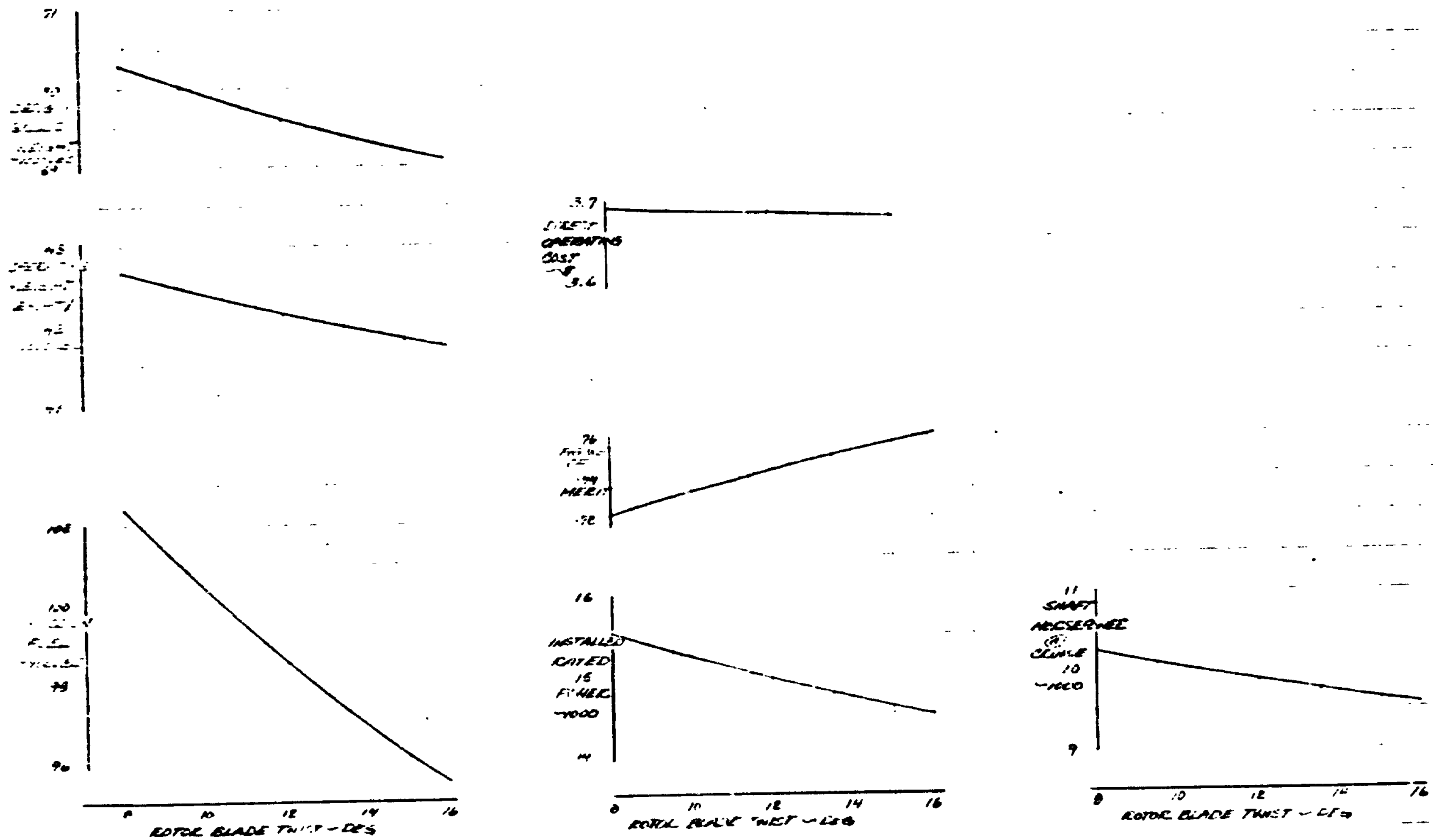


Figure 3.6

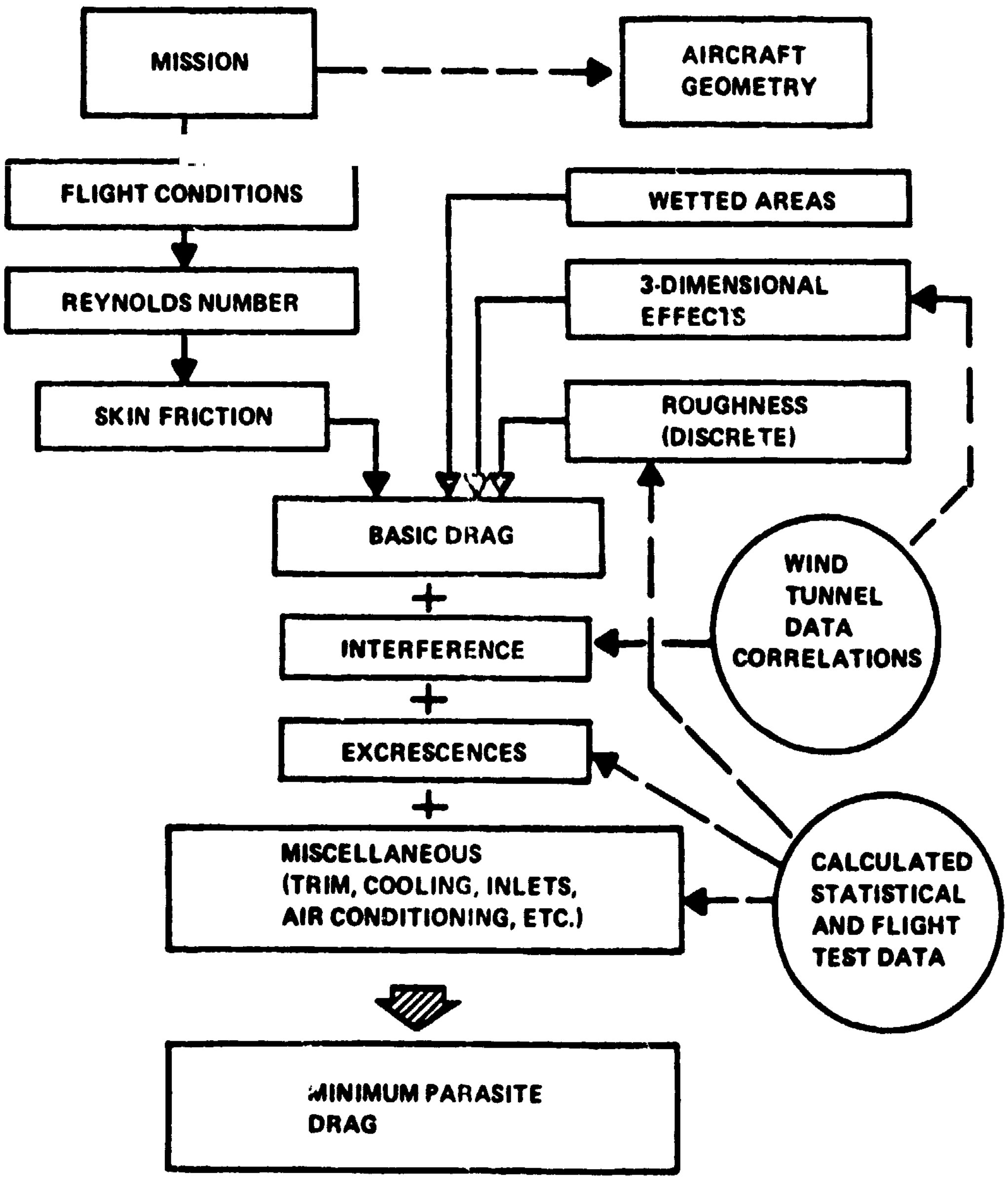


Figure 3.7. Minimum Parasite Drag Estimation Procedure.

TANDEM HELICOPTER DRAG SUMMARY

ITEM	DRAG AREA f_e - Ft^2
FUSELAGE	10.0193
FORWARD PYLON	2.8842
AFT PYLON	3.0609
NACELLES	1.4618
MISCELLANEOUS	
OIL COOLER MOMENTUM LOSS	.3000
AIR CONDITIONING	.5000
TRIM	.0900
SUB TOTAL	18.3162
ROTOR HUBS	20.2
TOTAL DRAG AREA	38.5162

$$\frac{GW}{f_e} = \frac{67175}{38.5162} = 1{,}744 \text{ LBS/FT}^2$$

TABLE 3.6. TANDEM HELICOPTER - BASELINE AIRCRAFT DRAG SUMMARY.

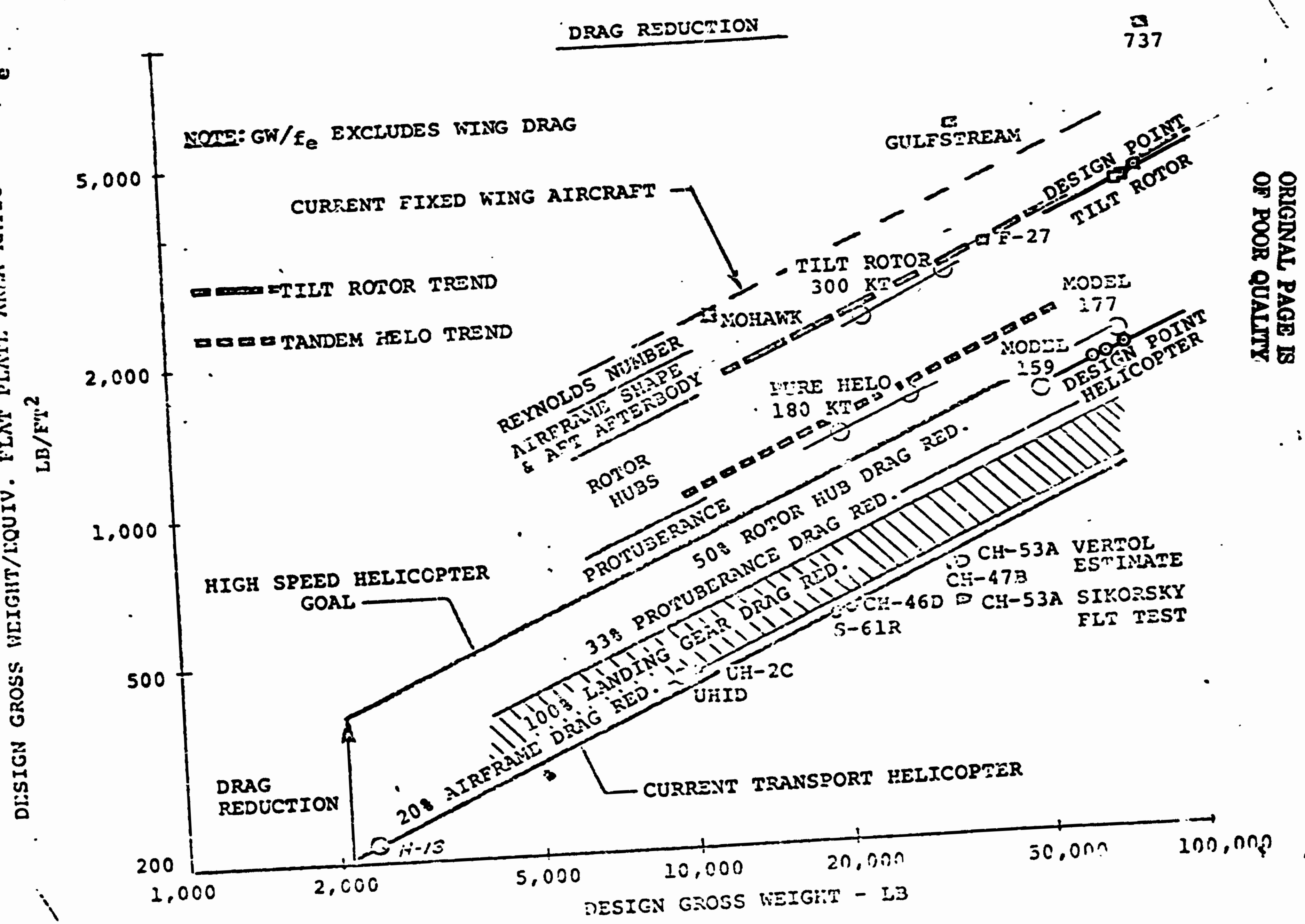


FIGURE 3.8. DRAG TREND COMPARISON.

Engine Performance (Helicopter)

The engines selected for the study was the AVCO Lycoming LTC4V-1 engine. This engine has an uninstalled engine rating of 5,000 SHP and a dry weight of 750 pounds. This power to weight ratio of .15 met the NASA criteria. The SFC of the engine was .418 at sea level standard, was less than the NASA criteria of .42 at takeoff power at sea level, 90 degrees F. The aircraft design takeoff ambient, therefore, the fuel flow was adjusted to comply with the design criteria.

Figures 3.9 and 3.10 give the referred installed performance of this engine used throughout this study as a function of turbine inlet temperature and flight Mach number.

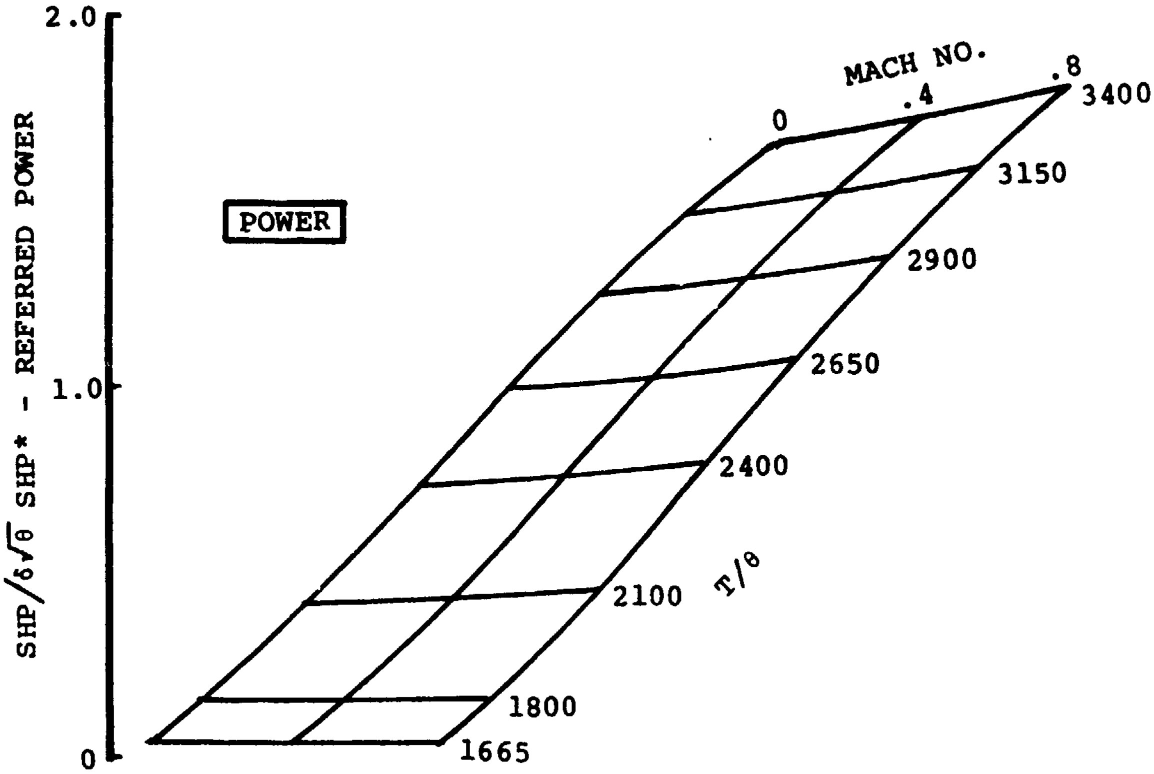
Referred Power is $\dfrac{SHP/\delta\sqrt{\theta}}{SHP^*}$

Referred Fuel Flow is $\dfrac{W_f/\delta\sqrt{\theta}}{SHP^*}$

Referred Compressor Speed is $\dfrac{N_I\sqrt{\theta}}{N_1^*}$

Referred Power Turbine Speed is $\dfrac{N_{II}\sqrt{\theta}}{N_{II}^*}$

The installation factors applied included inlet and exhaust losses and a 1% compressor bleed for air conditioning and pressurization. Accessory horsepowers of 150 SHP total are deducted during aircraft performance calculations and are, therefore, not included in the data of Figures 3.9 and 3.10.



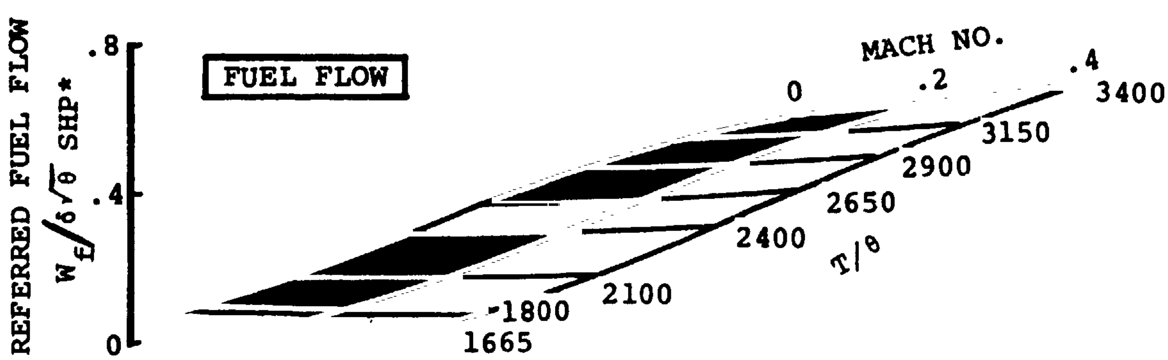


FIGURE 3.9. GENERALIZED HELICOPTER ENGINE PERFORMANCE - POWER AND FUEL FLOW.

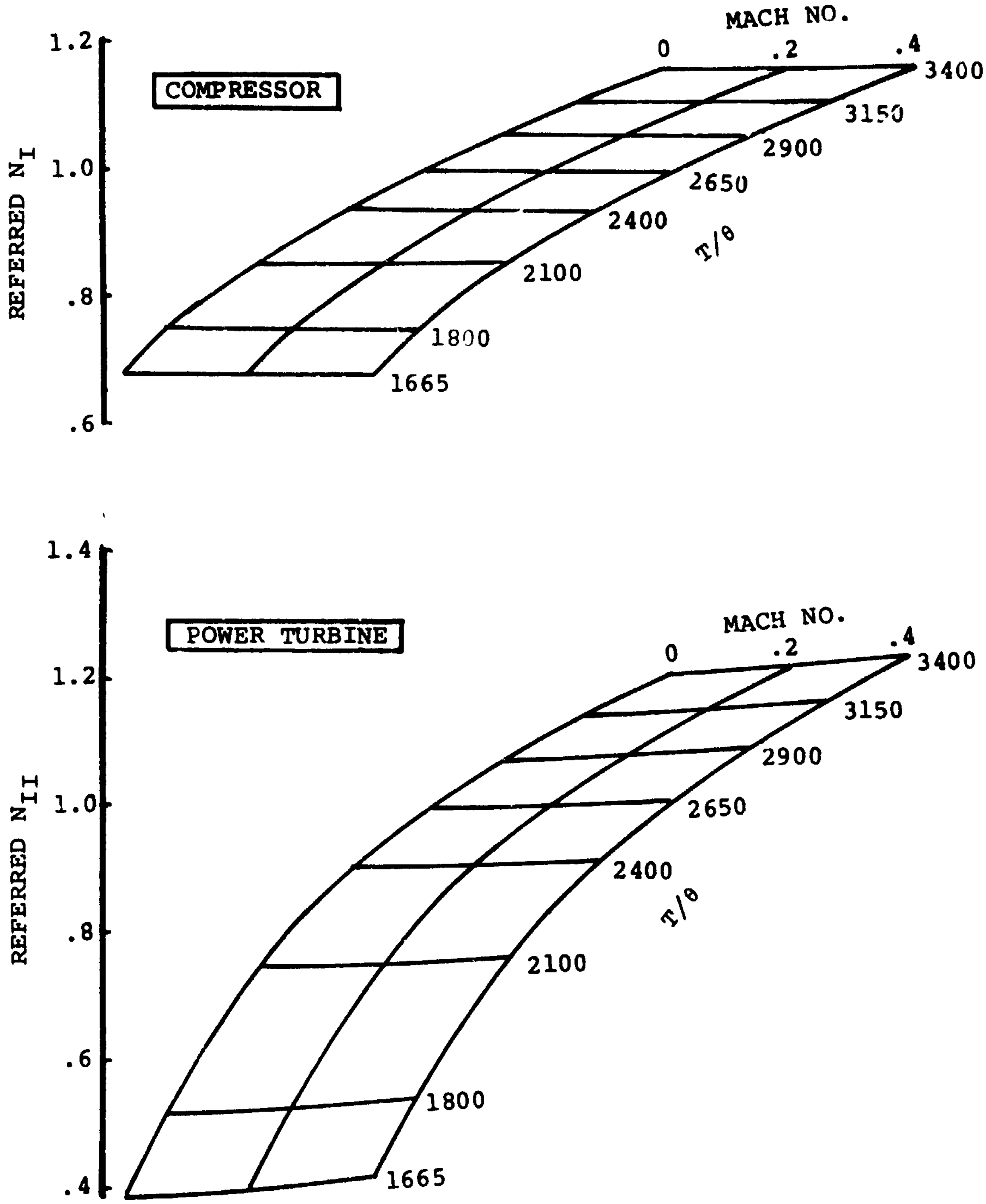


FIGURE 3.10. GENERALIZED HELICOPTER ENGINE PERFORMANCE - COMPRESSOR AND POWER TURBINE SPEED.

Tilt Rotor Aircraft

The tilt rotor aircraft were sized and the mission performance data obtained using VASCOMP. This computer program was developed for NASA by Boeing Vertol Company under NASA Contract NAS2-3142. This program works in a similar manner to the HESCOMP program except that it is specifically designed to handle V/STOL configurations. The details of this methodology are reported in Reference 2.

The tilt rotor aircraft mission performance data are given as summaries in Volume I. The detailed mission performance calculations are provided in Tables 3.7 to 3.9 for the baseline and ±5 PNdB noise derivative aircraft.

Tilt Rotor - Download and Ground Effect

Hover tests, conducted between 1967 and 1970 led to the development of the leading edge umbrella flaps for the Model 222: these are used to reduce download on the wing from rotor wake. The tests included exploratory studies of various leading and trailing edge devices at the Princeton University smoke tunnel, wind tunnel model tests on a model with 5.5 foot diameter rotors at the Boeing Vertol V/STOL wind tunnel, and a full scale test at the Wright Field whirl tower using a CH-47A rotor and scaled wing. Data from these tests are summarized in Figure 3.11. The summary shown the effect on download of leading and trailing edge configuration and of ground proximity. Based on these data, the following download to thrust ratios (DL/T) have been used in this study:

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ITERATION 2 W/A#15 VT#775 PAGE 6

V A S C O M P II
V/STOL AIRCRAFT SIZING & PERFORMANCE COMPUTER PROGRAM B-93

MISSION PERFORMANCE DATA

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	LETF
0.0	0.C	0.0	74749.	C.	0.0	1725.0	T	0.0	0.0
0.017	C.C	13.9	74735.	0.	0.0	1725.0	T	0.C	0.0

TAKEOFF, HOVER, OR LAND AT T/W = 1.101 FOR 0.033 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	LETF	THRUST TO WEIGHT	FM	BHP	CT	VTIP (FPS)
0.017	0.C	13.9	74735.	0.	0.0	2520.8	P	0.838	0.0	1.101	0.767	12150.	0.0950	775.
0.025	C.C	59.2	74690.	0.	0.0	2520.2	P	0.838	0.0	1.101	0.767	12139.	0.0950	775.
0.033	C.C	104.4	74644.	0.	0.0	2519.5	P	0.837	0.0	1.101	0.767	12128.	0.0949	775.
0.042	0.C	149.6	74599.	0.	0.0	2518.9	P	0.836	0.0	1.101	0.767	12117.	0.0949	775.
0.050	0.C	193.1	74556.	0.	0.0	2518.3	P	0.835	0.0	1.101	0.767	12106.	0.0948	775.

CLIMB TO 14000. FT. WITH MAXIMUM R/C AT MILITARY ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/C (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.050	C.C	193.1	74556.	0.	174.2	2580.0	T	0.574	174.2	0.263	0.518	13.9	20.0	4227.
0.941	0.0858	10.965	72387.	6602.	6768.	16155.		24413.	0.0382	0.0266	1.193	775.0	0.830	
0.054	0.67	219.8	74529.	1000.	174.0	2580.0	T	0.555	171.5	0.264	0.515	13.5	20.0	4121.
0.973	0.0954	10.885	72465.	6657.	6615.	15836.		23958.	0.0386	0.0269	1.191	775.0	0.830	
0.058	1.35	246.5	74502.	2000.	173.6	2580.0	T	0.537	168.6	0.264	0.511	13.1	20.0	3999.
1.008	0.0934	10.751	72552.	6723.	6463.	15516.		23530.	0.0389	0.0272	1.189	775.0	0.830	
0.062	2.06	273.5	74475.	3000.	173.2	2580.0	T	0.518	165.7	0.264	0.507	12.7	20.0	3872.
1.044	0.0977	10.685	72640.	6798.	6312.	15199.		23101.	0.0393	0.0275	1.186	775.0	0.830	
0.066	2.78	300.6	74448.	4000.	173.0	2580.0	T	0.517	163.0	0.265	0.502	12.4	20.0	3754.
1.080	0.1021	10.574	72722.	6878.	6163.	14887.		22654.	0.0397	0.0278	1.185	775.0	0.830	
0.071	3.54	328.0	74421.	5000.	172.8	2580.0	T	0.519	160.4	0.266	0.498	12.0	20.0	3630.
1.117	0.1068	10.454	72804.	6964.	6015.	14596.		22236.	0.0401	0.0281	1.183	775.0	0.830	
0.075	4.31	355.6	74393.	6000.	172.6	2580.0	T	0.521	157.8	0.266	0.494	11.6	20.0	3502.
1.155	0.1119	10.325	72986.	7059.	5867.	14301.		21811.	0.0405	0.0284	1.182	775.0	0.830	
0.080	5.12	383.5	74365.	7000.	172.4	2580.0	T	0.523	155.2	0.267	0.489	11.1	20.0	3369.
1.195	0.1173	10.187	72969.	7163.	5722.	14003.		21382.	0.0409	0.0287	1.180	775.0	0.830	

TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY.

0.085	5.55	411.8	74337.	8000.	172.2	2580.0	T	0.924	152.7	0.268	0.484	10.7	20.0	3231.
1.237	0.1232	10.040	73052.	7276.	5577.	13703.		20948.	0.0413	0.0290	1.179	775.0	0.830	
0.090	6.63	440.6	74308.	9000.	174.6	2580.0	T	0.926	152.4	0.272	0.484	9.7	19.1	2970.
1.245	0.1241	10.030	73253.	7303.	5436.	13412.		20225.	0.0417	0.0289	1.195	775.0	0.830	
0.096	7.79	471.1	74278.	10000.	178.2	2580.0	T	0.928	153.1	0.279	0.485	8.9	18.2	2785.
1.235	0.1226	10.071	73399.	7287.	5297.	13126.		19390.	0.0421	0.0286	1.220	775.0	0.830	
0.102	8.85	502.8	74246.	11000.	182.1	2580.0	T	0.929	154.1	0.286	0.486	8.8	17.9	2810.
1.220	0.1209	10.100	73380.	7265.	5161.	12842.		18561.	0.0425	0.0283	1.247	775.0	0.830	
0.108	9.92	533.4	74215.	12000.	185.9	2580.0	T	0.931	154.8	0.293	0.487	7.7	16.7	2520.
1.212	0.1154	10.147	73548.	7248.	5027.	12557.		17782.	0.0429	0.0280	1.273	775.0	0.830	
0.114	11.14	566.7	74182.	13000.	189.6	2580.0	T	0.932	155.3	0.300	0.488	7.2	16.1	2394.
1.204	0.1184	10.172	73603.	7236.	4894.	12272.		17042.	0.0433	0.0277	1.298	775.0	0.830	
0.121	12.45	600.7	74148.	14000.	193.2	2580.0	T	0.934	155.8	0.307	0.489	6.6	15.5	2265.
1.197	0.1175	10.154	73650.	7225.	4764.	11987.		16331.	0.0436	0.0274	1.323	775.0	0.830	

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.121	12.45	600.7	74148.	14000.	349.4	2500.0	T	0.580	281.7	0.555	0.585	.07233	0.824
0.369	0.0424	8.706	74148.	8517.	4830.	11374.		8509.	0.1207	0.0291	3.417	542.5	
0.143	20.00	705.2	74043.	14000.	349.5	2500.0	T	0.580	281.7	0.556	0.585	.07234	0.824
0.366	0.0423	8.696	74043.	8515.	4831.	11375.		8507.	0.1207	0.0291	3.418	542.5	
0.172	30.00	843.4	73905.	14000.	349.6	2500.0	T	0.580	281.8	0.556	0.585	.07236	0.824
0.367	0.0423	8.682	73905.	8513.	4831.	11376.		8505.	0.1207	0.0291	3.419	542.5	
0.200	40.00	981.6	73767.	14000.	349.7	2500.0	T	0.580	281.9	0.556	0.585	.07238	0.824
0.366	0.0422	8.668	73767.	8511.	4831.	11377.		8503.	0.1207	0.0291	3.420	542.5	
0.229	50.00	1119.8	73629.	14000.	349.8	2500.0	T	0.580	282.0	0.556	0.585	.07240	0.824
0.365	0.0422	8.654	73629.	8508.	4832.	11378.		8501.	0.1208	0.0291	3.422	542.5	
0.257	60.00	1257.9	73491.	14000.	349.9	2500.0	T	0.580	282.1	0.556	0.585	.07242	0.924
0.364	0.0422	8.640	73490.	8506.	4832.	11379.		8499.	0.1208	0.0291	3.423	542.5	
0.286	70.00	1396.0	73352.	14000.	350.1	2500.0	T	0.580	282.2	0.556	0.585	.07244	0.824
0.363	0.0421	8.626	73352.	8504.	4832.	11381.		8497.	0.1208	0.0291	3.424	542.5	
0.315	80.00	1534.0	73214.	14000.	350.2	2500.0	T	0.580	282.3	0.557	0.585	.07246	0.824
0.362	0.0421	8.611	73214.	8502.	4833.	11382.		8495.	0.1208	0.0291	3.425	542.5	
0.343	90.00	1672.0	73076.	14000.	350.3	2500.0	T	0.580	282.4	0.557	0.585	.07248	0.824
0.362	0.0421	8.597	73076.	8500.	4833.	11383.		8493.	0.1208	0.0291	3.426	542.5	
0.372	100.00	1810.0	72938.	14000.	350.4	2500.0	T	0.580	282.5	0.557	0.586	.07250	0.824
0.361	0.0420	8.583	72938.	8498.	4833.	11384.		8491.	0.1208	0.0290	3.427	542.5	

TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY. (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

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0.400	110.00	1947.9	72800.	14000.	350.5	2500.0	T	0.980	282.6	0.557	0.586	.07252	0.824
0.360	0.0420	8.569	72800.	8496.	4834.	11385.		8488.	0.1208	0.0290	3.428	542.5	
0.429	120.00	2085.8	72662.	14000.	350.6	2500.0	T	0.981	282.7	0.557	0.586	.07253	0.824
0.359	0.0419	8.555	72662.	8493.	4834.	11386.		8486.	0.1208	0.0290	3.430	542.5	
0.457	130.00	2223.7	72525.	14000.	350.8	2500.0	T	0.981	282.8	0.558	0.586	.07255	0.824
0.358	0.0419	8.541	72524.	8491.	4834.	11387.		8484.	0.1209	0.0290	3.431	542.5	
0.486	140.00	2361.5	72387.	14000.	350.9	2500.0	T	0.981	282.9	0.558	0.586	.07257	0.824
0.357	0.0419	8.527	72387.	8489.	4835.	11388.		8482.	0.1209	0.0290	3.432	542.5	
0.514	150.00	2499.3	72249.	14000.	351.0	2500.0	T	0.981	283.0	0.558	0.586	.07259	0.824
0.356	0.0418	8.513	72249.	8487.	4835.	11389.		8480.	0.1209	0.0290	3.433	542.5	
0.543	160.00	2637.1	72111.	14000.	351.1	2500.0	T	0.981	283.1	0.558	0.586	.07261	0.824
0.355	0.0418	8.498	72111.	8485.	4835.	11390.		8478.	0.1209	0.0290	3.434	542.5	
0.571	170.00	2774.8	71973.	14000.	351.2	2500.0	T	0.981	283.2	0.558	0.586	.07263	0.824
0.354	0.0417	8.484	71973.	8483.	4836.	11391.		8476.	0.1209	0.0290	3.435	542.5	
0.576	171.82	2799.8	71948.	14000.	351.2	2500.0	T	0.981	283.2	0.558	0.586	.07263	0.824
0.354	0.0417	8.482	71948.	8483.	4836.	11391.		8476.	0.1209	0.0290	3.435	542.5	

DESCEND TO H = 2000. FT. ,R = 200.00 N.MI. AT FLIGHT IDLE

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEMF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/S (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.576	171.82	2799.8	71948.	14000.	374.3	1740.0	T	0.257	301.8	0.595	0.591	-6.2	-6.8	4073.
0.310	0.0400	7.740	71532.	9242.	1434.	2981.		1516.	0.0316	0.0052	3.661	542.5	0.600	
0.581	173.34	2805.6	71942.	13000.	372.2	1740.0	T	0.254	305.0	0.590	0.592	-5.9	-6.6	3870.
0.304	0.0398	7.625	71575.	9387.	1443.	2949.		1507.	0.0303	0.0050	3.641	542.5	0.600	
0.585	174.53	2811.8	71936.	12000.	366.3	1740.0	T	0.250	305.0	0.578	0.592	-5.3	-6.0	3413.
0.304	0.0398	7.630	71641.	9389.	1449.	2898.		1505.	0.0288	0.0048	3.583	542.5	0.600	
0.590	176.72	2818.9	71929.	11000.	360.6	1740.0	T	0.245	305.0	0.567	0.592	-5.3	-6.0	3383.
0.304	0.0398	7.629	71630.	9389.	1454.	2842.		1500.	0.0274	0.0047	3.527	542.5	0.600	
0.595	178.49	2826.1	71922.	10000.	290.9	1740.0	T	0.221	250.0	0.456	0.575	-1.6	-0.7	832.
0.454	0.0464	9.779	71895.	7352.	1437.	2560.		1675.	0.0239	0.0050	2.845	542.5	0.600	
0.615	184.32	2854.9	71893.	9000.	286.4	1740.0	T	0.215	250.0	0.447	0.575	-4.1	-3.2	2060.
0.453	0.0464	9.767	71712.	7343.	1443.	2490.		1655.	0.0225	0.0048	2.801	542.5	0.600	
0.623	186.63	2866.5	71881.	8000.	282.0	1740.0	T	0.208	250.0	0.438	0.575	-4.1	-3.2	2045.
0.453	0.0464	9.766	71697.	7342.	1448.	2414.		1629.	0.0212	0.0046	2.758	542.5	0.600	
0.631	188.92	2878.3	71870.	7000.	277.7	1740.0	T	0.201	250.0	0.430	0.575	-4.1	-3.3	2033.
0.453	0.0463	9.765	71682.	7341.	1452.	2330.		1597.	0.0198	0.0044	2.716	542.5	0.600	
0.639	191.20	2890.2	71858.	6000.	273.4	1740.0	T	0.193	250.0	0.422	0.575	-4.2	-3.3	2022.
0.452	0.0463	9.774	71666.	7340.	1456.	2239.		1558.	0.0185	0.0041	2.675	542.5	0.600	

TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY. (CONTINUED)

0.647	193.44	2902.2	71846.	5000.	269.3	1740.0	T	0.184	250.0	0.414	0.575	-4.2	-3.4	2015.
0.452	0.0463	9.762	71649.	7339.	1459.	2141.		1513.	0.0171	0.0039	2.634	542.5	0.600	
0.656	195.67	2914.3	71833.	4000.	265.3	1740.0	T	0.173	250.0	0.407	0.575	-4.3	-3.4	2015.
0.452	0.0463	9.761	71631.	7338.	1459.	2009.		1441.	0.0156	0.0036	2.595	542.5	0.600	
0.664	197.86	2926.4	71821.	3000.	261.3	1740.0	T	0.160	250.0	0.399	0.575	-4.4	-3.5	2020.
0.452	0.0463	9.760	71612.	7337.	1455.	1863.		1356.	0.0140	0.0033	2.556	542.5	0.600	
0.672	200.01	2938.4	71809.	2000.	257.5	1740.0	T	0.148	250.0	0.392	0.575	-4.5	-3.6	2027.
0.452	0.0463	9.759	71592.	7336.	1450.	1713.		1266.	0.0125	0.0030	2.518	542.5	0.600	

LOITER FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	EAS	MACH	MACH DIV	FUEL RATE (LB-HR)	ETAP PROP
CL	CP	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP
0.672	200.01	2938.4	71809.	2000.	138.4	1967.0	P	0.431	134.3	0.211	0.446	2620.	0.706
1.570	0.1774	8.851	71809.	8113.	2620.	5008.		8109.	0.0366	0.0191	1.353	542.5	0.706
0.697	200.01	3003.9	71744.	2000.	138.4	1966.6	P	0.431	134.3	0.211	0.446	2617.	0.706
1.569	0.1771	8.856	71744.	8101.	2617.	5000.		8097.	0.0366	0.0191	1.353	542.5	0.706

DESCEND TO H = 1000. FT. AT FLIGHT IDLE

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/S (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.697	200.01	3003.9	71744.	2030.	257.5	1740.0	T	0.148	250.0	0.392	0.575	-4.8	-4.0	2285.
0.451	0.0463	9.752	71487.	7331.	1450.	1713.		1266.	0.0125	0.0030	2.518	542.5	0.600	
0.701	200.58	3009.4	71738.	1500.	255.6	1740.0	T	0.141	250.0	0.388	0.575	-4.5	-3.6	2833.
0.452	0.0463	9.754	71517.	7332.	1447.	1634.		1216.	0.0118	0.0028	2.500	542.5	0.600	
0.705	202.02	3015.3	71732.	1000.	253.7	1740.0	T	0.134	250.0	0.385	0.575	-4.5	-3.7	2838.
0.451	0.0463	9.753	71507.	7332.	1443.	1552.		1164.	0.0110	0.0027	2.481	542.5	0.600	

TRANSFER ALTITUDE TO 0. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.705	202.02	3015.3	71732.	1000.
0.705	202.02	3015.3	71732.	0.

TAKEOFF, HOVER, OR LAND AT T/W = 1.101 FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	LETF	THRUST TO WEIGHT	FN	BHP	CT	VTIP (FPS)

TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY. (CONTINUED)

0.705	202.02	3015.3	71732.	0.	0.0	2480.4	P	0.788	0.0	1.101	0.767	11425.	0.0912	775.
0.713	202.02	3058.4	71689.	0.	0.0	2479.8	P	0.788	0.0	1.101	0.767	11415.	0.0912	775.
0.722	202.02	3101.5	71646.	0.	0.0	2475.2	P	0.787	0.0	1.101	0.767	11405.	0.0911	775.
0.730	202.02	3143.5	71604.	0.	0.0	2478.7	P	0.786	0.0	1.101	0.767	11394.	0.0910	775.

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	LETF
0.730	202.02	3143.5	71604.	0.	0.0	1725.0	T	0.0	0.0
0.747	202.02	3157.4	71590.	0.	0.0	1725.0	T	0.0	0.0

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.747	202.02	3157.4	71590.	0.
0.747	202.02	3157.4	71590.	5000.

LOITER FOR 0.333 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	FUEL RATE (LB-HR)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP
0.747	202.02	3157.4	71590.	5000.	143.6	1987.5	P	0.455	133.3	0.221	0.444	2635.	0.698
1.590	0.1811	8.783	71590.	8151.	2635.	5285.		8147.	0.0423	0.0210	1.404	542.5	0.698
0.847	202.02	3420.9	71327.	5000.	143.6	1985.3	P	0.452	133.3	0.221	0.444	2623.	0.698
1.584	0.1800	8.803	71327.	8103.	2623.	5253.		8099.	0.0421	0.0209	1.404	542.5	0.698
0.947	202.02	3683.2	71064.	5000.	142.6	1983.1	P	0.450	132.4	0.219	0.442	2612.	0.699
1.601	0.1820	8.747	71064.	8125.	2612.	5221.		8121.	0.0418	0.0210	1.395	542.5	0.699
1.047	202.02	3944.4	70803.	5000.	142.6	1980.8	P	0.447	132.4	0.219	0.443	2600.	0.699
1.595	0.1819	8.767	70803.	8076.	2600.	5190.		8072.	0.0416	0.0208	1.395	542.5	0.699
1.080	202.02	4030.2	70717.	5000.	142.6	1980.1	P	0.446	132.4	0.219	0.443	2596.	0.699
1.593	0.1816	8.773	70717.	8060.	2596.	5180.		8056.	0.0415	0.0208	1.395	542.5	0.699

CRUISE AT BEST RANGE SPEED WITH HEADWIND OF 0.0 KNOTS

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.747	202.02	4030.2	71590.	5000.	242.3	2083.6	P	0.606	224.9	0.373	0.563	.07499	0.731
0.558	0.0525	10.626	71590.	6738.	3232.	7037.		6734.	0.0563	0.0174	2.370	542.5	
0.780	210.00	4136.6	71484.	5000.	242.3	2083.1	P	0.605	224.9	0.373	0.563	.07505	0.731
0.557	0.0525	10.621	71484.	6731.	3229.	7030.		6727.	0.0563	0.0174	2.370	542.5	
[illegible]	[illegible]	4269.8	71351.	5000.	242.3	2082.5	P	0.605	224.9	0.373	0.563	.07514	0.731

TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY. (CONTINUED)

0.556	0.C524	10.614	71351.	6722.	3225.	7021.		6719.	0.0562	0.0173	2.37C	542.5	
0.862 0.560	23C.CO C.C527	44C2.9 10.636	71217. 71217.	5000. 6696.	241.3 3208.	2075.9 6975.	P	0.601 6693.	224.0 0.0558	0.371 0.0173	0.563 2.360	.07522 542.5	0.730
0.904 0.554	240.CO 0.C526	4535.8 10.630	71084. 71084.	5000. 6687.	241.3 3205.	2079.3 6966.	P	0.600 6684.	224.0 0.0558	0.371 0.0173	0.563 2.360	.07530 542.5	0.730
0.945 0.558	250.CO 0.0525	4668.6 10.623	70952. 70952.	50C0. 6679.	241.3 3201.	2078.7 6957.	P	0.599 6675.	224.0 0.0557	0.371 0.0172	0.563 2.360	.07538 542.5	0.730
0.945 0.558	250.CO 0.0525	4668.6 10.623	70952. 70952.	50C0. 6679.	241.3 3201.	2078.7 6957.	P	0.599 6675.	224.0 0.0557	0.371 0.0172	0.563 2.36C	.07538 542.5	0.730

MISSICN FUEL REQUIRED = 3795.7C
RESERVE FUEL REQUIRED = 872.94
TCTAL FUEL REQUIRED = 4668.64

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OF POOR QUALITY

TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY. (CONTINUED)

3898

V A S C O M P II
V/STOL AIRCRAFT SIZING & PERFORMANCE COMPUTER PROGRAM 8-93

MISSION PERFORMANCE DATA

TAKEOFF, HOVER, OR LAND AT PETF = 1.000, LETF = 0.0 FOR 0.001 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	LETF	THRUST TO WEIGHT	FM	BHP	CT	VTIP (FPS)
0.0	0.0	0.0	74749.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.767	14478.	0.1067	775.
0.000	0.0	3.1	74746.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.767	14478.	0.1067	775.
0.001	0.0	6.3	74742.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.767	14478.	0.1067	775.
0.001	0.0	6.3	74742.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.767	14478.	0.1067	775.

TRANSFER ALTITUDE TO 14000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.001	0.0	6.3	74742.	0.
0.001	0.0	6.3	74742.	14000.

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.001	0.0	6.3	74742.	14000.	348.8	2500.0	T	0.979	281.2	0.555	0.584	.07224	0.824
0.373	0.0425	8.766	74742.	8526.	4829.	11370.		8518.	0.1207	0.0291	3.412	542.5	
0.015	5.00	75.5	74673.	14000.	348.9	2500.0	T	0.979	281.3	0.555	0.584	.07225	0.824
0.372	0.0425	8.759	74673.	8525.	4829.	11370.		8517.	0.1207	0.0291	3.413	542.5	

MISSION FUEL REQUIRED = 75.50
RESERVE FUEL REQUIRED = 0.0
TOTAL FUEL REQUIRED = 75.50

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END OF SUCCESSFUL CASE

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TABLE 3.7. BASELINE TILT ROTOR - MISSION TIME HISTORY. (CONTINUED)

112 ETA

V A S C O P P II
V/STOL AIRCRAFT SIZING & PERFORMANCE COMPUTER PROGRAM R-93

MISSION PERFORMANCE DATA

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	LETF
0.0	0.0	0.0	75692.	0.	0.0	1725.0	T	0.0	0.0
0.017	0.0	16.3	75676.	0.	0.0	1725.0	T	0.0	0.0

TAKEOFF, HOVER, OR LAND AT T/W = 1.101 FOR 0.033 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	LETF	THRUST TO WEIGHT	FM	SHP	CT	VTIP (FPS)
0.017	0.0	16.3	75676.	0.	0.0	2520.8	P	0.838	0.0	1.101	0.696	14273.	0.1393	640.
0.025	0.0	69.5	75612.	0.	0.0	2520.1	P	0.838	0.0	1.101	0.696	14258.	0.1392	640.
0.033	0.0	122.6	75559.	0.	0.0	2519.4	P	0.837	0.0	1.101	0.696	14244.	0.1392	640.
0.042	0.0	175.7	75506.	0.	0.0	2518.7	P	0.836	0.0	1.101	0.696	14230.	0.1391	640.
0.050	0.0	226.8	75455.	0.	0.0	2518.0	P	0.835	0.0	1.101	0.696	14216.	0.1390	640.

CLIMB TO 14000. FT. WITH MAXIMUM R/C AT MILITARY ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/C (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	SHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.050	0.0	226.8	75455.	0.	193.0	2580.0	T	0.579	193.0	0.292	0.535	15.8	20.0	5316.
0.760	0.0673	11.286	76443.	6775.	7972.	19078.		28343.	0.0752	0.0425	1.600	640.0	0.904	
0.053	0.58	251.8	75430.	1000.	192.8	2580.0	T	0.560	190.0	0.292	0.536	15.5	20.0	5222.
0.785	0.0696	11.270	76541.	6791.	7793.	18703.		27814.	0.0759	0.0429	1.595	640.0	0.904	
0.056	1.18	276.7	75405.	2000.	192.2	2580.0	T	0.542	186.6	0.292	0.533	15.2	20.0	5100.
0.815	0.0724	11.243	76634.	6816.	7614.	18326.		27339.	0.0766	0.0435	1.594	640.0	0.904	
0.060	1.78	301.5	75380.	3000.	191.6	2580.0	T	0.523	183.3	0.293	0.529	14.8	20.0	4975.
0.845	0.0755	11.201	76730.	6853.	7436.	17951.		26863.	0.0773	0.0440	1.589	640.0	0.904	
0.063	2.40	326.5	75355.	4000.	190.8	2580.0	T	0.517	179.8	0.292	0.525	14.5	20.0	4833.
0.880	0.0789	11.143	76836.	6895.	7259.	17582.		26420.	0.0780	0.0446	1.582	640.0	0.904	
0.066	3.04	351.5	75330.	5000.	190.2	2580.0	T	0.519	176.6	0.293	0.522	14.1	20.0	4690.
0.914	0.0825	11.072	76938.	6949.	7085.	17238.		25986.	0.0789	0.0452	1.577	640.0	0.904	
0.070	3.70	376.6	75305.	6000.	189.6	2580.0	T	0.520	173.3	0.293	0.517	13.7	20.0	4550.
0.949	0.0864	10.988	77041.	7013.	6912.	16891.		25543.	0.0797	0.0458	1.572	640.0	0.904	
0.074	4.37	401.9	75280.	7000.	189.0	2580.0	T	0.522	170.2	0.293	0.513	13.3	20.0	4413.
0.986	0.0906	10.185	77146.	7089.	6741.	16535.		25091.	0.0834	0.0464	1.567	640.0	0.904	

TABLE 3.8. -5 PNdB TILT ROTOR MISSION TIME HISTORY.

EPL 5754 (2)

0.077	5.06	427.4	79254.	8000.	188.4	2580.0	T	0.524	167.0	0.293	0.505	12.9	20.0	4263.
1.025	0.0552	10.769	77253.	7173.	6570.	16185.		24632.	0.0812	0.0470	1.562	640.0	0.904	
0.091	5.78	453.0	79228.	9000.	187.8	2580.0	T	0.526	163.9	0.293	0.504	12.5	20.0	4107.
1.066	0.1001	10.640	77362.	7271.	6402.	15829.		24167.	0.0819	0.0475	1.557	640.0	0.904	
0.085	6.53	479.0	79202.	10000.	187.4	2580.0	T	0.527	161.0	0.293	0.499	12.0	20.0	3958.
1.136	0.1053	10.504	77463.	7374.	6235.	15472.		23672.	0.0826	0.0481	1.550	640.0	0.904	
0.090	7.30	505.3	79176.	11000.	186.4	2580.0	T	0.529	157.7	0.293	0.494	11.5	20.0	3763.
1.155	0.1119	10.326	77569.	7507.	6069.	15111.		23243.	0.0832	0.0487	1.545	540.0	0.904	
0.074	8.11	532.2	79149.	12000.	188.5	2580.0	T	0.531	157.0	0.297	0.492	10.5	19.1	3477.
1.167	0.1135	10.304	77928.	7551.	5909.	14747.		22457.	0.0840	0.0496	1.563	640.0	0.904	
0.095	9.00	560.5	79121.	13000.	192.7	2580.0	T	0.532	157.9	0.305	0.494	9.5	18.0	3217.
1.159	0.1120	10.382	78039.	7539.	5754.	14435.		21483.	0.0848	0.0480	1.597	640.0	0.904	
0.134	9.58	590.3	79091.	14000.	196.0	2580.0	T	0.534	158.0	0.312	0.494	9.0	17.5	3109.
1.159	0.1120	10.347	78116.	7550.	5601.	14099.		20630.	0.0855	0.0476	1.625	640.0	0.904	

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PERF CR PEMF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.104	5.58	590.3	79091.	14000.	355.0	2500.0	T	0.584	286.2	0.564	0.586	.06235	0.755
0.357	0.0409	8.731	79091.	9059.	5694.	13422.		9053.	0.2373	0.0426	4.205	448.0	
0.132	20.00	750.9	78930.	14000.	355.1	2500.0	T	0.584	286.3	0.565	0.586	.06237	0.755
0.356	0.0409	8.715	78930.	9056.	5694.	13423.		9051.	0.2373	0.0426	4.206	448.0	
0.160	30.00	911.3	78770.	14000.	355.3	2500.0	T	0.584	286.4	0.565	0.586	.06239	0.755
0.355	0.0408	8.700	78770.	9054.	5695.	13424.		9048.	0.2373	0.0426	4.208	448.0	
0.188	40.00	1071.5	78610.	14000.	355.4	2500.0	T	0.584	286.5	0.565	0.586	.06241	0.755
0.354	0.0408	8.685	78610.	9052.	5695.	13426.		9046.	0.2373	0.0426	4.209	448.0	
0.217	50.00	1231.8	78450.	14000.	355.5	2500.0	T	0.584	286.6	0.565	0.586	.06242	0.755
0.353	0.0408	8.669	78449.	9049.	5695.	13427.		9044.	0.2374	0.0426	4.211	448.0	
0.245	60.00	1392.0	78289.	14000.	355.7	2500.0	T	0.584	286.7	0.565	0.586	.06244	0.755
0.352	0.0407	8.654	78289.	9047.	5696.	13428.		9041.	0.2374	0.0425	4.212	448.0	
0.273	70.00	1552.1	78129.	14000.	355.8	2500.0	T	0.585	286.9	0.566	0.587	.06246	0.755
0.351	0.0407	8.638	78129.	9044.	5696.	13430.		9039.	0.2374	0.0425	4.214	448.0	
0.301	80.00	1712.2	77969.	14000.	355.9	2500.0	T	0.585	287.0	0.566	0.587	.06248	0.755
0.351	0.0406	8.623	77969.	9042.	5697.	13431.		9037.	0.2374	0.0425	4.216	448.0	
0.329	90.00	1872.3	77809.	14000.	356.0	2500.0	T	0.585	287.1	0.566	0.587	.06250	0.755
0.350	0.0406	8.608	77809.	9040.	5697.	13432.		9034.	0.2375	0.0425	4.217	448.0	
0.357	100.00	2032.3	77649.	14000.	356.2	2500.0	T	0.585	287.2	0.566	0.587	.06251	0.755
0.349	0.0406	8.592	77649.	9037.	5698.	13434.		9032.	0.2375	0.0425	4.215	448.0	

TABLE 3.8. -5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

EPL 5724 (8)

0.385	110.00	2192.3	77489.	14000.	356.3	2500.0	T	0.585	287.3	0.566	0.587	.06253	0.755
0.348	0.0405	8.577	77489.	9035.	5698.	13435.		9030.	0.2375	0.0425	4.220	448.0	
0.413	120.00	2352.2	77329.	14000.	356.4	2500.0	T	0.585	287.4	0.567	0.587	.06255	0.755
0.347	0.0405	8.561	77329.	9033.	5698.	13436.		9027.	0.2375	0.0425	4.222	448.0	
0.441	130.00	2512.1	77169.	14000.	356.6	2500.0	T	0.585	287.5	0.567	0.587	.06257	0.755
0.346	0.0404	8.546	77169.	9030.	5699.	13438.		9025.	0.2376	0.0425	4.223	448.0	
0.469	140.00	2671.9	77009.	14000.	356.7	2500.0	T	0.585	287.6	0.567	0.587	.06258	0.755
0.345	0.0404	8.530	77009.	9028.	5699.	13439.		9023.	0.2376	0.0425	4.225	448.0	
0.497	150.00	2831.7	76849.	14000.	356.8	2500.0	T	0.585	287.7	0.567	0.587	.06260	0.755
0.344	0.0404	8.515	76849.	9026.	5700.	13440.		9020.	0.2376	0.0424	4.226	448.0	
0.525	160.00	2991.4	76690.	14000.	356.9	2500.0	T	0.585	287.8	0.567	0.588	.06262	0.755
0.343	0.0403	8.499	76690.	9023.	5700.	13442.		9018.	0.2376	0.0424	4.227	448.0	
0.553	170.00	3151.1	76530.	14000.	357.1	2500.0	T	0.586	287.9	0.568	0.588	.06263	0.755
0.342	0.0403	8.484	76530.	9021.	5701.	13443.		9016.	0.2377	0.0424	4.229	448.0	
0.553	170.01	3151.3	76530.	14000.	357.1	2500.0	T	0.586	287.9	0.568	0.588	.06263	0.755
0.342	0.0403	8.484	76530.	9021.	5701.	13443.		9016.	0.2377	0.0424	4.229	448.0	

DESCEND TO H = 2000. FT. ,R = 200.00 N.MI. AT FLIGHT IDLE

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (F)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/S (FPM)
CL	CC	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	EHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.553	170.01	3151.3	76530.	14000.	374.3	1740.0	T	0.257	301.8	0.595	0.591	-5.0	-6.5	3050.
0.309	0.0391	7.923	76136.	9609.	1685.	3502.		1640.	0.0619	0.0087	4.433	448.0	0.620	
0.558	171.62	3158.5	76522.	13000.	372.2	1740.0	T	0.254	305.0	0.590	0.592	-5.6	-6.3	3661.
0.333	0.0388	7.904	76173.	9758.	1695.	3464.		1830.	0.0593	0.0083	4.409	448.0	0.620	
0.562	173.31	3166.3	76515.	12000.	366.3	1740.0	T	0.250	305.0	0.578	0.592	-5.0	-5.7	3229.
0.333	0.0388	7.811	76235.	9763.	1702.	3404.		1827.	0.0564	0.0081	4.339	448.0	0.620	
0.569	175.26	3175.0	76506.	11000.	360.6	1740.0	T	0.245	305.0	0.567	0.592	-5.0	-5.7	3201.
0.333	0.0388	7.810	76222.	9760.	1709.	3338.		1821.	0.0536	0.0078	4.271	448.0	0.620	
0.573	177.07	3183.9	76497.	10000.	290.9	1740.0	T	0.221	250.0	0.456	0.575	-1.5	-0.6	778.
0.453	0.0455	9.960	76472.	7678.	1680.	3008.		2033.	0.0468	0.0084	3.446	448.0	0.620	
0.594	183.21	3220.1	76461.	9000.	286.4	1740.0	T	0.215	250.0	0.447	0.575	-3.8	-2.9	1527.
0.452	0.0454	9.948	76292.	7669.	1695.	2926.		2009.	0.0441	0.0081	3.392	448.0	0.620	
0.633	185.78	3234.8	76446.	8000.	282.0	1740.0	T	0.208	250.0	0.438	0.575	-3.8	-3.0	1915.
0.452	0.0454	9.947	76274.	7668.	1701.	2835.		1577.	0.0415	0.0077	3.340	448.0	0.620	
0.612	188.23	3249.6	76431.	7000.	277.7	1740.0	T	0.201	250.0	0.430	0.575	-3.9	-3.0	1980.
0.452	0.0454	9.946	76255.	7667.	1706.	2737.		1536.	0.0388	0.0073	3.285	448.0	0.620	
0.623	190.65	3264.5	76416.	6000.	273.4	1740.0	T	0.193	250.0	0.422	0.575	-3.9	-3.0	1899.
0.452	0.0454	9.945	76236.	7666.	1710.	2630.		1892.	0.0362	0.0069	3.239	448.0	0.620	

TABLE 3.8. -5 PNdB TILT ROTOR MISSITON TIME HISTORY. (CONTINUED)

EPL 724 9

0.629	193.05	3279.5	76401.	5000.	269.3	1740.0	T	0.184	250.0	0.414	0.575	-4.0	-3.1	1895.
0.451	0.0454	9.944	76217.	7665.	1714.	2515.		1836.	0.0335	0.0065	3.190	448.0	0.620	
0.638	195.41	3294.6	76386.	4000.	265.3	1740.0	T	0.173	250.0	0.407	0.575	-4.1	-3.2	1901.
0.451	0.0454	9.942	76195.	766[illegible]	1713.	2360.		1750.	0.0305	0.0060	3.142	448.0	0.620	
0.647	197.73	3309.6	76371.	3000.	261.3	1740.0	T	0.160	250.0	0.399	0.575	-4.1	-3.3	1911.
0.451	0.0454	9.941	76172.	7662.	1710.	2188.		1647.	0.0275	0.0055	3.095	448.0	0.620	
0.655	200.01	3324.5	76356.	2000.	257.5	1740.0	T	0.148	250.0	0.392	0.575	-4.2	-3.3	1923.
0.451	0.0454	9.940	76148.	7661.	1703.	2012.		1537.	0.0245	0.0050	3.050	448.0	0.620	

LOITER FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	EAS	MACH	MACH DIV	FUEL RATE (LB-HR)	ETAP PROP
CL	CC	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP
0.655	200.01	3324.5	76356.	2000.	152.2	1870.8	P	0.311	147.8	0.232	0.478	2472.	0.880
1.294	0.1317	9.826	76356.	7771.	2472.	4236.		7767.	0.0516	0.0252	1.803	448.0	0.880
0.680	200.01	3386.3	76294.	2000.	152.2	1870.5	P	0.310	147.8	0.232	0.478	2470.	0.880
1.293	0.1315	9.830	76294.	7761.	2470.	4231.		7757.	0.0516	0.0252	1.803	448.0	0.880

DESCEND TO H = 1000. FT. AT FLIGHT IDLE

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/S (FPM)
CL	CC	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.680	200.01	3386.3	76294.	2000.	257.5	1740.0	T	0.148	250.0	0.392	0.575	-4.6	-3.7	2092.
0.450	0.0453	9.933	76048.	7656.	170[illegible]	2012.		1537.	0.0245	0.0050	3.050	448.0	0.620	
0.684	201.03	3393.1	76287.	1500.	255.6	1740.0	T	0.141	250.0	0.388	0.575	-4.3	-3.4	1532.
0.451	0.0454	9.935	76075.	7657.	1699.	1919.		1477.	0.0230	0.0047	3.027	448.0	0.620	
0.689	202.13	3400.4	76280.	1000.	253.7	1740.0	T	0.134	250.0	0.385	0.575	-4.3	-3.5	1540.
0.450	0.0453	9.934	76062.	7657.	1695.	1823.		1413.	0.0216	0.0045	3.005	448.0	0.620	

TRANSFER ALTITUDE TO 0. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.689	202.13	3400.4	76280.	1000.
0.689	202.13	3400.4	76280.	0.

TAKEOFF, HOVER, OR LAND AT T/W = 1.101 FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEHF	LETF	THRUST TO WEIGHT	FM	BHP	CT	VTIP (FPS)

TABLE 3.8. -5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

ER 5724 (9)

0.689	202.13	3400.4	76280.	0.	0.0	2478.0	P	0.785	0.0	1.101	0.696	13373.	0.1334	640.
0.697	202.13	3450.9	76230.	0.	0.0	2477.4	P	0.785	0.0	1.101	0.696	13359.	0.1333	640.
0.705	202.13	3501.4	76179.	0.	0.0	2476.8	P	0.784	0.0	1.101	0.696	13346.	0.1332	640.
0.714	202.13	3550.6	76130.	0.	0.0	2476.2	P	0.783	0.0	1.101	0.696	13333.	0.1332	640.

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	LETF
0.714	202.13	3550.6	76130.	0.	0.0	1725.0	T	0.0	0.0
0.730	202.13	3566.9	76113.	0.	0.0	1725.0	T	0.0	0.0

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.730	202.13	3566.9	76113.	0.
0.730	202.13	3566.9	76113.	5000.

LOITER FOR 0.333 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	FUEL RATE (LB-HR)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP
0.730	202.13	3566.9	76113.	5000.	154.5	1874.3	P	0.324	143.4	0.238	0.469	2427.	0.880
1.371	0.1437	9.539	76113.	7579.	2427.	4413.		7575.	0.0589	0.0283	1.829	448.0	0.880
0.830	202.13	3809.6	75871.	5000.	154.5	1873.0	P	0.322	143.4	0.238	0.469	2419.	0.880
1.366	0.1430	9.555	75871.	7940.	2419.	4392.		7936.	0.0586	0.0282	1.829	448.0	0.880
0.930	202.13	4051.5	75629.	5000.	154.5	1871.6	P	0.320	143.4	0.238	0.470	2412.	0.880
1.362	0.1423	9.572	75629.	7901.	2412.	4370.		7897.	0.0583	0.0280	1.829	448.0	0.880
1.030	202.13	4292.7	75388.	5000.	154.5	1870.3	P	0.319	143.4	0.238	0.470	2404.	0.880
1.358	0.1416	9.588	75387.	7863.	2404.	4349.		7859.	0.0580	0.0279	1.829	448.0	0.880
1.063	202.13	4372.1	75308.	5000.	154.5	1865.8	P	0.318	143.4	0.238	0.471	2402.	0.880
1.356	0.1414	9.593	75308.	7850.	2402.	4342.		7846.	0.0579	0.0279	1.829	448.0	0.880

CRUISE AT BEST RANGE SPEED WITH HEADWIND OF 0.0 KNOTS

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.730	202.13	4372.1	76113.	5000.	234.3	1956.4	P	0.438	217.5	0.360	0.558	.07983	0.857
0.556	0.0543	10.977	76113.	6934.	2938.	5974.		6930.	0.0797	0.0246	2.775	448.0	
0.764	210.00	4470.6	76015.	5000.	234.3	1956.0	P	0.438	217.5	0.360	0.559	.07989	0.857
0.595	0.0542	10.974	76015.	6927.	2936.	5968.		6923.	0.0796	0.0246	2.775	448.0	
0.807	220.00	4595.8	75890.	5000.	234.3	1955.6	P	0.437	217.5	0.360	0.559	.07997	0.857

TABLE 3.8. -5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

EPL 5724 (10)

0.594	0.0541	10.970	75890.	6518.	2933.	5960.		6915.	0.0795	0.0245	2.775	448.0	
0.349	230.00	4720.8	75765.	5000.	233.3	1952.8	P	0.433	216.6	0.359	0.558	.08004	0.858
0.598	0.0544	10.987	75765.	6896.	2915.	5909.		6892.	0.0788	0.0245	2.763	448.0	
0.642	240.00	4845.8	75640.	5000.	233.3	1952.3	P	0.433	216.6	0.359	0.558	.08012	0.858
0.597	0.0543	10.983	75640.	6887.	2912.	5902.		6883.	0.0787	0.0244	2.763	448.0	
0.935	250.00	4970.6	75515.	5000.	233.3	1951.9	P	0.432	216.6	0.359	0.558	.08019	0.858
0.596	0.0543	10.979	75515.	6878.	2910.	5894.		6875.	0.0786	0.0244	2.763	448.0	
0.935	250.00	4970.6	75515.	5000.	233.3	1951.9	P	0.432	216.6	0.359	0.558	.08019	0.858
0.596	0.0543	10.979	75515.	6878.	2910.	5894.		6875.	0.0786	0.0244	2.763	448.0	

MISSION FUEL REQUIRED = 4165.32
RESERVE FUEL REQUIRED = 805.25
TOTAL FUEL REQUIRED = 4970.57

TABLE 3.8. -5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

SPNDB 10CPASS DES FCTAT VT4640 FPS PAGE 7 EPL 5724 (11)

V A S C C M P II
V/STOL AIRCRAFT SIZING & PERFORMANCE COMPUTER PROGRAM B-93

MISSION PERFORMANCE DATA

TAKEOFF, HOVER, OR LAND AT PETF = 1.000, LETF = 0.0 FOR 0.001 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	LETF	THRUST TO WEIGHT	FM	SHP	CT	VTIP (FPS)
0.0	0.0	0.0	75682.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.696	17000.	0.1565	640.
0.001	0.0	7.4	75675.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.696	17000.	0.1565	640.

TRANSFER ALTITUDE TO 14000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.001	0.0	7.4	75675.	0.
0.001	0.0	7.4	79675.	14000.

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CR PEMF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	SHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.001	0.0	7.4	75675.	14000.	354.5	2500.0	T	0.584	285.8	0.564	0.586	.06228	0.755
0.361	0.0411	8.786	75674.	9068.	5692.	13416.		9062.	0.2372	0.0426	4.195	448.0	
0.015	5.00	87.7	75594.	14000.	354.6	2500.0	T	0.584	285.9	0.564	0.586	.06229	0.755
0.360	0.0411	8.779	79594.	9067.	5692.	13417.		9061.	0.2372	0.0426	4.200	448.0	

MISSION FUEL REQUIRED = 87.67
RESERVE FUEL REQUIRED = 0.0
TOTAL FUEL REQUIRED = 87.67

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END OF SUCCESSFUL CASE

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TABLE 3.8. -5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

VASCOMP II
V/STOL AIRCRAFT SIZING & PERFORMANCE COMPUTER PROGRAM B-93

MISSION PERFORMANCE DATA

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEHF	LETF
0.0	0.0	0.0	73217.	0.	0.0	1725.0	T	0.0	0.0
0.017	0.0	13.5	73204.	0.	0.0	1725.0	T	0.0	0.0

TAKEOFF, HOVER, OR LAND AT T/W = 1.101 FOR 0.033 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEHF	LETF	THRUST TO WEIGHT	FM	BHP	CT	VTIP (FPS)
0.017	0.0	13.5	73204.	0.	0.0	2520.8	P	0.838	0.0	1.101	0.775	11778.	0.0682	915.
0.025	0.0	57.3	73160.	0.	0.0	2520.2	P	0.838	0.0	1.101	0.775	11768.	0.0681	915.
0.033	0.0	101.2	73116.	0.	0.0	2519.5	P	0.837	0.0	1.101	0.775	11757.	0.0681	915.
0.042	0.0	145.0	73072.	0.	0.0	2518.9	P	0.836	0.0	1.101	0.775	11746.	0.0680	915.
0.050	0.0	187.2	73030.	0.	0.0	2518.3	P	0.835	0.0	1.101	0.775	11736.	0.0680	915.

CLIMB TO 14000. FT. WITH MAXIMUM R/C AT MILITARY ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEHF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/C (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	PHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.050	0.0	187.2	73030.	0.	175.0	2580.0	T	0.974	175.0	0.264	0.520	14.0	20.0	4280.
0.932	0.0850	10.965	70871.	6463.	6562.	15663.		24045.	0.0230	0.0192	1.015	915.0	0.847	
0.054	0.66	212.7	73305.	1000.	174.8	2580.0	T	0.955	172.3	0.265	0.516	13.6	20.0	4175.
0.963	0.0884	10.891	70948.	6514.	6414.	15354.		23597.	0.0232	0.0194	1.014	915.0	0.847	
0.058	1.34	238.3	72979.	2000.	174.4	2580.0	T	0.937	169.2	0.265	0.512	13.3	20.0	4054.
0.998	0.0924	10.803	71034.	6575.	6266.	15045.		23175.	0.0234	0.0196	1.011	915.0	0.847	
0.062	2.04	264.1	72953.	3000.	174.0	2580.0	T	0.918	166.5	0.266	0.508	12.9	20.0	3928.
1.034	0.0966	10.703	71120.	6645.	6120.	14737.		22752.	0.0236	0.0198	1.009	915.0	0.847	
0.066	2.76	290.1	72927.	4000.	173.6	2580.0	T	0.917	163.6	0.266	0.503	12.5	20.0	3797.
1.072	0.1012	10.591	71208.	6724.	5974.	14434.		22336.	0.0239	0.0201	1.007	915.0	0.847	
0.071	3.50	316.3	72901.	5000.	173.4	2580.0	T	0.919	161.6	0.267	0.499	12.1	20.0	3674.
1.108	0.1058	10.475	71289.	6806.	5831.	14151.		21924.	0.0241	0.0203	1.006	915.0	0.847	
0.075	4.27	342.7	72874.	6000.	173.2	2580.0	T	0.921	158.3	0.267	0.495	11.7	20.0	3547.
1.147	0.1106	10.350	71371.	6896.	5688.	13865.		21506.	0.0244	0.0205	1.004	915.0	0.847	
0.080	5.07	369.5	72848.	7000.	173.0	2580.0	T	0.923	155.8	0.268	0.490	11.2	20.0	3415.
1.186	0.1161	10.216	71453.	6994.	5547.	13577.		21083.	0.0246	0.0208	1.003	915.0	0.847	

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY.

5765 (7)

0.085	5.90	396.5	72821.	8000.	172.8	2580.0	T	0.924	153.2	0.269	0.485	10.8	20.0	3277.
1.228	0.1219	10.073	71534.	7102.	5407.	13286.		20655.	0.0248	0.0210	1.002	915.0	0.847	
0.090	6.76	424.0	72793.	9000.	173.7	2580.0	T	0.926	151.7	0.271	0.482	10.1	19.6	3083.
1.255	0.1257	9.985	71669.	7178.	5269.	12998.		20097.	0.0250	0.0211	1.008	915.0	0.847	
0.095	7.69	452.5	72765.	10000.	177.5	2580.0	T	0.928	152.6	0.278	0.484	9.0	18.4	2824.
1.244	0.1239	10.041	71862.	7157.	5135.	12721.		19251.	0.0253	0.0208	1.030	915.0	0.847	
0.101	8.72	482.8	72734.	11000.	180.7	2580.0	T	0.929	152.5	0.284	0.484	9.0	18.3	2857.
1.238	0.1234	10.035	71844.	7159.	5002.	12442.		18494.	0.0255	0.0206	1.048	915.0	0.847	
0.107	9.77	512.0	72705.	12000.	185.1	2580.0	T	0.931	154.1	0.292	0.486	7.8	16.9	2538.
1.221	0.1208	10.114	72037.	7122.	4872.	12169.		17658.	0.0258	0.0203	1.074	915.0	0.847	
0.114	10.97	544.0	72673.	13000.	188.8	2580.0	T	0.932	154.7	0.299	0.487	7.3	16.4	2436.
1.213	0.1197	10.138	72081.	7110.	4744.	11893.		16922.	0.0260	0.0201	1.095	915.0	0.847	
0.120	12.25	576.5	72641.	14000.	192.5	2580.0	T	0.934	155.2	0.306	0.488	6.8	15.8	2305.
1.207	0.1188	10.160	72131.	7099.	4617.	11617.		16214.	0.0262	0.0199	1.116	915.0	0.847	

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF C9 PEHF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.120	12.25	576.5	72641.	14000.	340.9	2500.0	T	0.973	274.9	0.542	0.582	.07317	0.800
0.337	0.0435	8.907	72641.	8156.	4659.	10952.		8151.	0.0721	0.0204	2.824	640.5	
0.143	20.00	682.3	72535.	14000.	341.0	2500.0	T	0.973	274.9	0.542	0.583	.07319	0.800
0.337	0.0435	8.896	72535.	8154.	4659.	10953.		8150.	0.0721	0.0204	2.825	640.5	
0.172	30.00	818.9	72398.	14000.	341.1	2500.0	T	0.973	275.0	0.542	0.583	.07321	0.800
0.396	0.0434	8.881	72398.	8152.	4660.	10954.		8147.	0.0721	0.0204	2.826	640.5	
0.202	40.00	955.5	72261.	14000.	341.3	2500.0	T	0.973	275.1	0.543	0.583	.07323	0.800
0.335	0.0434	8.867	72261.	8149.	4660.	10955.		8145.	0.0721	0.0204	2.827	640.5	
0.231	50.00	1092.1	72125.	14000.	341.4	2500.0	T	0.973	275.3	0.543	0.583	.07326	0.800
0.383	0.0433	8.853	72125.	8147.	4660.	10956.		8143.	0.0721	0.0204	2.828	640.5	
0.260	60.00	1228.6	71988.	14000.	341.5	2500.0	T	0.974	275.4	0.543	0.583	.07328	0.800
0.382	0.0433	8.839	71988.	8145.	4661.	10957.		8141.	0.0721	0.0204	2.829	640.5	
0.290	70.00	1365.1	71852.	14000.	341.7	2500.0	T	0.974	275.5	0.543	0.583	.07330	0.800
0.381	0.0432	8.824	71852.	8143.	4661.	10958.		8138.	0.0721	0.0204	2.830	640.5	
0.319	80.00	1501.5	71715.	14000.	341.8	2500.0	T	0.974	275.6	0.543	0.583	.07332	0.800
0.380	0.0432	8.810	71715.	8140.	4661.	10960.		8136.	0.0722	0.0204	2.832	640.5	
0.348	90.00	1637.9	71579.	14000.	341.9	2500.0	T	0.974	275.7	0.544	0.583	.07335	0.800
0.379	0.0431	8.796	71579.	8138.	4662.	10961.		8134.	0.0722	0.0204	2.833	640.5	
0.377	100.00	1774.2	71442.	14000.	342.0	2500.0	T	0.974	275.8	0.544	0.583	.07337	0.800
0.378	0.0431	8.781	71442.	8136.	4662.	10962.		8132.	0.0722	0.0204	2.834	640.5	

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

5765 (8)

0.407	110.00	1910.5	71306.	14000.	342.2	2500.0	T	0.974	275.9	0.544	0.584	.07339	0.800	
0.377	0.0431	8.767	71306.	8134.	4662.	10963.		8129.	0.0722	0.0204	2.835	640.5		
0.436	120.00	2046.8	71170.	14000.	342.3	2500.0	T	0.974	276.0	0.544	0.584	.07341	0.800	
0.376	0.0430	8.752	71170.	8131.	4663.	10964.		8127.	0.0722	0.0204	2.836	640.5		
0.465	130.00	2183.0	71034.	14000.	342.4	2500.0	T	0.974	276.1	0.544	0.584	.07343	0.800	
0.375	0.0430	8.738	71034.	8129.	4663.	10965.		8125.	0.0722	0.0204	2.837	640.5		
0.494	140.00	2319.2	70897.	14000.	342.6	2500.0	T	0.974	276.2	0.545	0.584	.07345	0.800	
0.374	0.0429	8.724	70897.	8127.	4664.	10966.		8123.	0.0722	0.0204	2.838	640.5		
0.523	150.00	2455.3	70761.	14000.	342.7	2500.0	T	0.974	276.3	0.545	0.584	.07348	0.800	
0.373	0.0429	8.709	70761.	8125.	4664.	10967.		8121.	0.0722	0.0203	2.839	640.5		
0.553	160.00	2591.4	70625.	14000.	342.8	2500.0	T	0.975	276.4	0.545	0.584	.07350	0.800	
0.372	0.0428	8.695	70625.	8123.	4664.	10969.		8119.	0.0722	0.0203	2.840	640.5		
0.582	170.00	2727.5	70489.	14000.	342.9	2500.0	T	0.975	276.5	0.545	0.584	.07352	0.800	
0.371	0.0428	8.680	70489.	8121.	4665.	10970.		8117.	0.0722	0.0203	2.841	640.5		
0.587	171.90	2753.3	70463.	14000.	343.0	2500.0	T	0.975	276.5	0.545	0.584	.07352	0.800	
0.371	0.0428	8.677	70463.	8120.	4665.	10970.		8116.	0.0722	0.0203	2.841	640.5		

DESCEND TO H = 2000. FT. ,R = 200.00 N.MI. AT FLIGHT IDLE

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PEPF OR PEMF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/S (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.587	171.90	2753.3	70463.	14000.	374.3	1740.0	T	0.257	301.8	0.595	0.591	-6.2	-6.9	4095.
0.310	0.0404	7.676	70051.	9126.	1391.	2890.		1518.	0.0190	0.0038	3.101	640.5	0.620	
0.591	173.42	2758.9	70457.	13000.	372.2	1740.0	T	0.254	305.0	0.590	0.592	-5.9	-6.7	3892.
0.304	0.0401	7.561	70093.	9271.	1399.	2858.		1510.	0.0182	0.0037	3.084	640.5	0.620	
0.596	175.00	2764.9	70451.	12000.	366.3	1740.0	T	0.250	305.0	0.578	0.592	-5.3	-6.0	3432.
0.304	0.0402	7.566	70159.	9273.	1405.	2809.		1508.	0.0173	0.0035	3.035	640.5	0.620	
0.601	176.78	2771.7	70445.	11000.	360.6	1740.0	T	0.245	305.0	0.567	0.592	-5.3	-6.1	3402.
0.304	0.0402	7.565	70148.	9273.	1410.	2755.		1502.	0.0165	0.0034	2.987	640.5	0.620	
0.605	178.54	2778.6	70438.	10000.	290.9	1740.0	T	0.221	250.0	0.456	0.575	-1.6	-0.7	834.
0.454	0.0467	9.714	70412.	7248.	1393.	2482.		1678.	0.0144	0.0037	2.410	640.5	0.620	
0.625	184.35	2806.5	70410.	9000.	286.4	1740.0	T	0.215	250.0	0.447	0.575	-4.1	-3.2	2064.
0.453	0.0467	9.702	70231.	7239.	1399.	2414.		1658.	0.0136	0.0035	2.373	640.5	0.620	
0.633	186.66	2817.8	70398.	8000.	282.0	1740.0	T	0.208	250.0	0.438	0.575	-4.1	-3.2	2049.
0.453	0.0467	9.701	70217.	7238.	1404.	2340.		1632.	0.0127	0.0034	2.336	640.5	0.620	
0.642	188.95	2829.2	70387.	7000.	277.7	1740.0	T	0.201	250.0	0.430	0.575	-4.2	-3.3	2037.
0.452	0.0466	9.700	70202.	7237.	1408.	2259.		1600.	0.0119	0.0032	2.300	640.5	0.620	
0.650	191.22	2840.7	70375.	6000.	273.4	1740.0	T	0.193	250.0	0.422	0.575	-4.2	-3.3	2027.
0.452	0.0466	9.699	70137.	7237.	1412.	2171.		1561.	0.0111	0.0030	2.265	640.5	0.620	

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

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0.658	193.46	2852.3	70364.	5000.	269.3	1740.0	T	0.184	250.0	0.414	0.575	-4.2	-3.4	2020.
0.452	0.0466	9.698	70171.	7236.	1415.	2075.		1515.	0.0103	0.0029	2.231	640.5	0.620	
0.666	195.68	2864.0	70352.	4000.	265.3	1740.0	T	0.173	250.0	0.407	0.575	-4.3	-3.4	2021.
0.452	0.0466	9.697	70153.	7235.	1414.	1948.		1444.	0.0094	0.0026	2.198	640.5	0.620	
0.675	197.86	2875.7	70340.	3000.	261.3	1740.0	T	0.160	250.0	0.399	0.575	-4.4	-3.5	2026.
0.452	0.0466	9.695	70134.	7234.	1411.	1806.		1359.	0.0084	0.0024	2.165	640.5	0.620	
0.683	200.01	2887.3	70329.	2000.	257.5	1740.0	T	0.148	250.0	0.392	0.575	-4.5	-3.6	2033.
0.452	0.0466	9.694	70115.	7233.	1406.	1660.		1268.	0.0075	0.0022	2.133	640.5	0.620	

LOITER FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEMF	EAS	MACH	MACH DIV	FUEL RATE (LB-HP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP
0.683	200.01	2887.3	70329.	2000.	150.3	1930.3	P	0.386	146.0	0.229	0.474	2326.	0.790
1.330	0.1369	9.713	70329.	7241.	2326.	4342.		7237.	0.0197	0.0125	1.246	640.5	0.790
0.708	200.31	2945.4	70271.	2000.	150.3	1930.0	P	0.385	146.0	0.229	0.474	2324.	0.790
1.328	0.1367	9.717	70271.	7232.	2324.	4337.		7228.	0.0197	0.0125	1.246	640.5	0.790

DESCEND TO H = 1000. FT. AT FLIGHT IDLE

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEMF	EAS	MACH	MACH DIV	GAMMA (DEG)	THETA -F (DEG)	R/S (FPM)
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP	
0.708	200.31	2945.4	70271.	2000.	257.5	1740.0	T	0.148	250.0	0.392	0.575	-4.9	-4.0	2213.
0.451	0.0466	9.687	70017.	7228.	1406.	1660.		1268.	0.0075	0.0022	2.133	640.5	0.620	
0.712	200.98	2950.7	70265.	1500.	255.6	1740.0	T	0.141	250.0	0.388	0.575	-4.5	-3.7	2040.
0.451	0.0466	9.689	70047.	7229.	1402.	1584.		1219.	0.0071	0.0021	2.117	640.5	0.620	
0.716	202.02	2956.4	70260.	1000.	253.7	1740.0	T	0.134	250.0	0.385	0.575	-4.6	-3.7	2045.
0.451	0.0466	9.689	70037.	7229.	1399.	1506.		1166.	0.0066	0.0020	2.102	640.5	0.620	

TRANSFER ALTITUDE TO 0. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.716	202.02	2956.4	70260.	1000.
0.716	202.02	2956.4	70260.	0.

TAKEOFF, HOVER, OR LAND AT T/W = 1.101 FOR 0.025 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEMF	LETF	THRUST TO WEIGHT	FN	BHP	CT	VTIP (FPS)

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

0.716	232.02	2956.4	70260.	0.	0.0	2480.3	P	0.788	0.0	1.101	0.775	11075.	0.0654	915.
0.724	232.02	2998.2	70218.	0.	0.0	2479.7	P	0.788	0.0	1.101	0.775	.1065.	0.0654	915.
0.732	232.02	3040.0	70176.	0.	0.0	2479.2	P	0.787	0.0	1.101	0.775	11055.	0.0654	915.
0.741	232.02	3080.7	70135.	0.	0.0	2478.6	P	0.786	0.0	1.101	0.775	11045.	0.0653	915.

TAXI FOR 0.017 HRS. AT GROUND IDLE ENGINE RATING

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(10)

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (F)	ENG. CODE	PETF OR PEHF	LETF
0.741	232.02	3080.7	70135.	0.	0.0	1725.0	T	0.0	0.0
0.757	202.02	3094.2	70122.	0.	0.0	1725.0	T	0.0	0.0

TRANSFER ALTITUDE TO 5000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.757	232.02	3094.2	70122.	0.
0.757	232.02	3094.2	70122.	5000.

LOITER FOR 0.333 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEHF	EAS	MACH	MACH DIV	FUEL RATE (LB-HR)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	ETAP
0.757	232.02	3094.2	70122.	5000.	154.6	1936.9	P	0.397	143.5	0.238	0.469	2303.	0.800
1.372	0.1435	9.561	70122.	7334.	2303.	4466.		7331.	0.0222	0.0139	1.281	640.5	0.800
0.857	232.02	3324.5	69891.	5000.	154.6	1935.2	P	0.395	143.5	0.238	0.469	2295.	0.800
1.367	0.1428	9.577	69891.	7298.	2295.	4444.		7294.	0.0221	0.0138	1.281	640.5	0.800
0.957	202.02	3553.9	69662.	5000.	154.6	1933.6	P	0.393	143.5	0.238	0.470	2267.	0.800
1.363	0.1421	9.593	69662.	7262.	2287.	4422.		7258.	0.0220	0.0137	1.281	640.5	0.800
1.057	232.02	3782.6	69433.	5000.	154.6	1931.9	P	0.391	143.5	0.238	0.470	2279.	0.800
1.358	0.1414	9.609	69433.	7226.	2279.	4400.		7222.	0.0219	0.0137	1.281	640.5	0.800
1.090	202.02	3857.8	69358.	5000.	154.6	1931.4	P	0.390	143.5	0.238	0.470	2276.	0.800
1.357	0.1411	9.614	69358.	7214.	2276.	4393.		7210.	0.0218	0.0136	1.281	640.5	0.800

CRUISE AT BEST RANGE SPEED WITH HEADWIND OF 0.0 KNOTS

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEHF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.757	232.02	3857.8	70122.	5000.	224.3	2020.4	P	0.514	208.2	0.345	0.552	.08159	0.781
0.652	0.0593	10.980	70122.	6386.	2750.	5780.		6363.	0.0287	0.0121	1.658	640.5	
0.793	210.03	3955.7	70024.	5000.	224.3	2019.9	P	0.513	208.2	0.345	0.552	.08166	0.781
0.651	0.0593	10.978	70024.	6379.	2747.	5774.		6376.	0.0287	0.0121	1.858	640.5	
0.817	220.03	4078.1	69901.	5000.	224.3	2019.3	P	0.512	208.2	0.345	0.552	.08176	0.781

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

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0.649	0.9592	10.974	69901.	6370.	2744.	5765.		6360.	0.0286	0.0120	1.858	640.5	
0.882	230.00	4200.4	69779.	5000.	224.3	2018.7	P	0.511	208.2	0.345	0.552	.08195	0.781
0.648	0.9591	10.971	69779.	6360.	2741.	5757.		6357.	0.0286	0.0120	1.858	640.5	
0.927	240.00	4322.6	69657.	5000.	224.3	2018.1	P	0.511	208.2	0.345	0.552	.08195	0.781
0.647	0.0590	10.967	69657.	6351.	2738.	5749.		6348.	0.0286	0.0120	1.858	640.5	
0.971	250.00	4444.6	69535.	5000.	224.3	2017.5	P	0.510	208.2	0.345	0.553	.08204	0.781
0.646	0.0589	10.964	69535.	6342.	2734.	5740.		6339.	0.0285	0.0120	1.858	640.5	
0.971	250.00	4444.6	69535.	5000.	224.3	2017.5	P	0.510	208.2	0.345	0.553	.08204	0.781
0.646	0.9589	10.964	69535.	6342.	2734.	5740.		6339.	0.0285	0.0120	1.858	640.5	

MISSION FUEL REQUIRED = 3680.88
RESERVE FUEL REQUIRED = 763.75
TOTAL FUEL REQUIRED = 4444.63

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

V A S C O M P II
V/STOL AIRCRAFT SIZING & PERFORMANCE COMPUTER PROGRAM B-93

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MISSION PERFORMANCE DATA

TAKEOFF, HOVER, OR LAND AT PETF = 1.000, LETF = 0.0 FOR 0.001 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF OR PEMF	LETF	THRUST TO WEIGHT	FM	BHP	CT	VTIP (FPS)
0.0	0.0	0.0	73217.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.775	14035.	0.0766	915.
0.001	0.0	6.1	73211.	0.	0.0	2660.1	T	1.000	0.0	1.237	0.775	14035.	0.0766	915.

TRANSFER ALTITUDE TO 14000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
0.001	0.0	6.1	73211.	0.
0.001	0.0	6.1	73211.	14000.

CRUISE AT NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	TURB. TEMP. (R)	ENG. CODE	PETF CP PEMF	EAS	MACH	MACH DIV	SPEC. RANGE (NMPP)	ETAP PROP
CL	CD	L/D	LIFT (LBS)	DRAG (LBS)	FUEL FLOW (LBS/HR)	BHP		THRUST (LBS)	CP	CT	J	VTIP (FPS)	
0.001	0.0	6.1	73211.	14000.	340.3	2500.0	T	0.973	274.4	0.541	0.582	.07308	0.800
0.392	0.0437	8.966	73211.	8165.	4657.	10947.		8161.	0.0721	0.0204	2.820	640.5	
0.016	5.00	74.5	73143.	14000.	340.4	2500.0	T	0.973	274.5	0.541	0.582	.07339	0.800
0.391	0.0437	8.959	73143.	8164.	4650.	10947.		8160.	0.0721	0.0204	2.820	640.5	

MISSION FUEL REQUIRED = 74.52
RESERVE FUEL REQUIRED = 0.0
TOTAL FUEL REQUIRED = 74.52

END OF SUCCESSFUL CASE

TABLE 3.9. +5 PNdB TILT ROTOR MISSION TIME HISTORY. (CONTINUED)

Out of ground effect, OGE (h/D > 2.0):

$$\frac{DL}{T} = 0.05$$

In ground effect, IGE (h/D = 0.51):

$$\frac{DL}{T} = -0.04$$

These values of download to thrust have been combined, in this study, with a specified lift to weight ratio (L/W) to determine the required aircraft thrust to weight ratio:

$$\frac{T}{W} = \frac{L/W}{1-DL/T}$$

The following thrust to weight ratios have been used for the hover ceiling data of this report:

TABLE 3.10. VALUES OF TILT ROTOR T/W IN HOVER.

	VALUE OF L/W	
	1.03	1.05
OGE	1.0815	1.111
IGE	0.9527	0.972

Rotor Performance Prediction

To properly design a rotor or propeller for a vehicle, an assessment of the cruise speed requirement and the hover requirements must be made with the objective of minimizing the rotor weight and the total power required. To do this trade-off, comparisons of hover and cruise performance for families of rotors utilizing various combinations of twist, blade number,

airfoils, etc. must be carried out. The data resulting from this comparison are then placed into the aircraft sizing programs to establish the effect on aircraft size, weight, power and fuel consumption and indicate if the rotor design should be biased to achieve high speed cruise performance or improved hover performance.

In order to accurately reflect variations in rotor design parameters, Boeing has developed rotor performance programs B-92 (Propeller-rotor hover and axial cruise flight performance) and B-67 (helicopter rotor (edgewise flight) cruise performance). Both of these programs utilize the "explicit - vortex influence-technique". This method consists of a strip analysis procedure coupled with non-uniform inflow calculations. Each blade is treated as a rotating lifting line, trailing a vortex wake which is mathematically approximated by a finite number of concentrated vortex filaments. An iterative computation is followed to make the induced flow at the disc, determined by the trailing vortices, mutually consistent with the spanwise aerodynamic loading distribution.

These programs account for:

- o blade geometry
    - taper
    - airfoil distribution
- o number of blades
- o rotor tip speeds
- o required lift

- o required propulsive force
- o airfoil aerodynamics based on wind tunnel test data
- o inflow, and
- o orientation of the rotor axis to the flight path.

Figure 3.12 illustrates summaries of comparisons between predicted and test data for various rotor and propeller configurations. This methodology was used to optimize the prop rotor performance for the design point aircraft as shown in Figures 3.13 to 3.15. The initial parametric data shown in Figure 3.13 are used to define the maximum performance envelope shown in Figure 3.14.

The rotor solidity and twist vary along the maximum performance envelope and aircraft were sized using a family of prop/rotors along this line.

These aircraft vary in gross weight and direct operating costs as shown in Figure 3.15. The optimum prop/rotor for this aircraft has a solidity of 0.08 and a twist of 34 degrees. The minimum solidity selected from structural considerations was 0.09 and therefore the prop/rotor corresponding to that point was selected for the aircraft.

Tilt Rotor Drag

The minimum drag of the tilt rotor has been calculated using the standard Boeing method of Reference 3. This method is based on surveys of existing data and the application of semi-empirical methods. The method provides a component build-up of drag as shown in Table 3.11. The drag estimate is shown

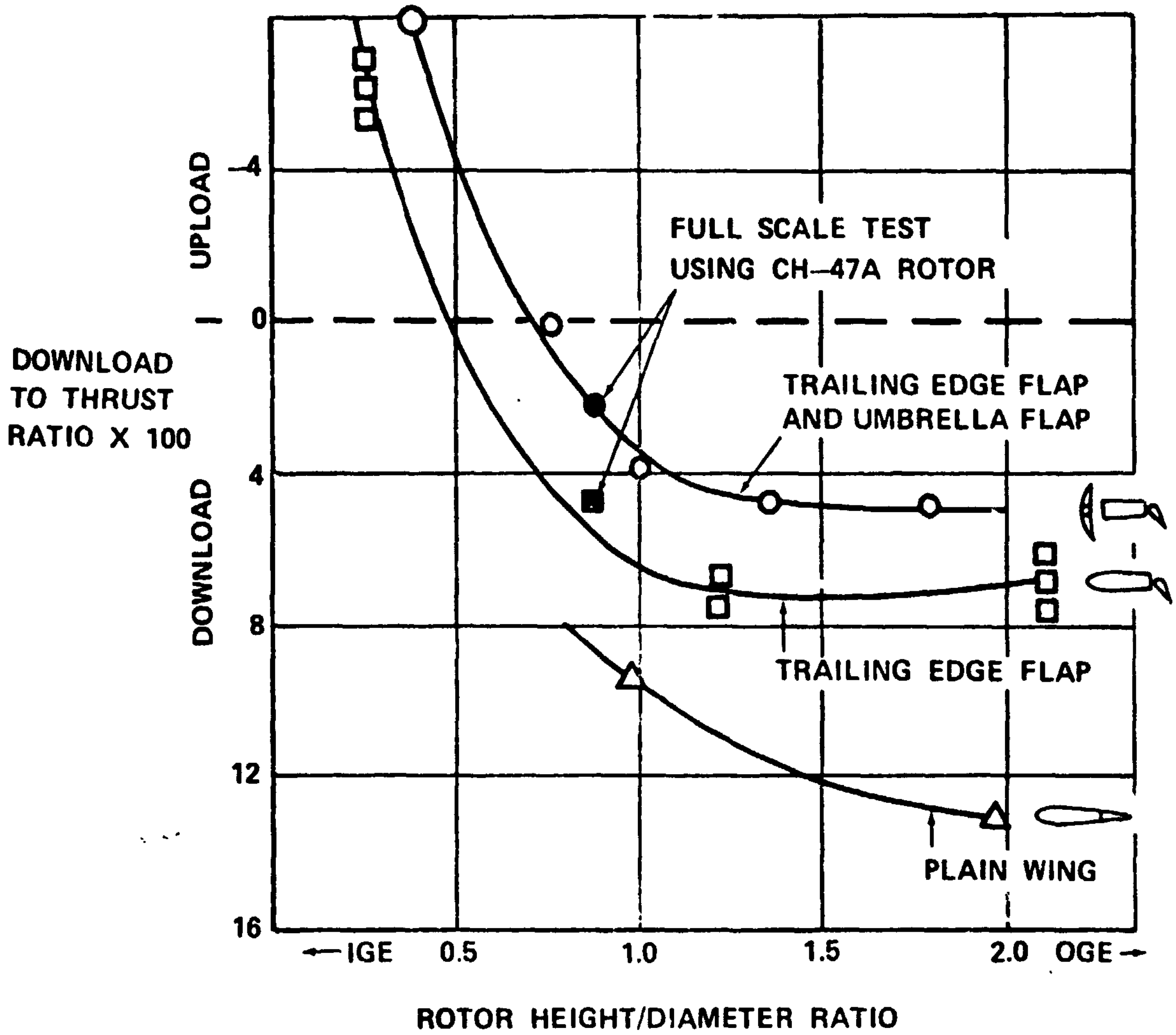

FIGURE 3.11. ROTOR TO WING DOWNLOAD.

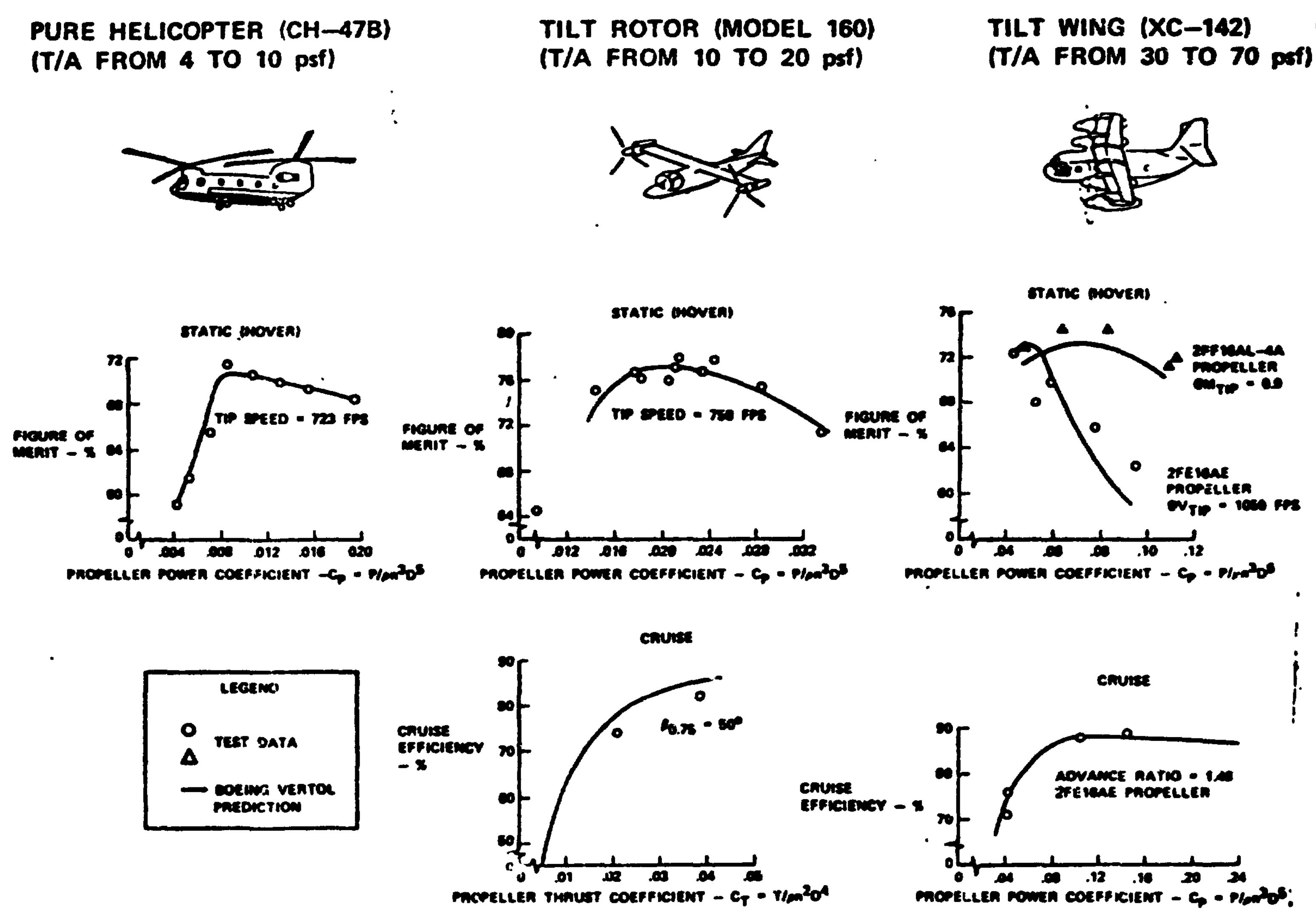

FIGURE 3.12. COMPARISON OF PREDICTED AND ACTUAL PERFORMANCE FOR THE SPECTRUM OF V/STOL PROPELLERS.

TILT ROTOR ROTOR DESIGN STUDY

$V_{T_{HOV}}$ = 775 FPS $V_{TIP_{CRUISE}}$ = 542 FPS

W/A = 15 PSF

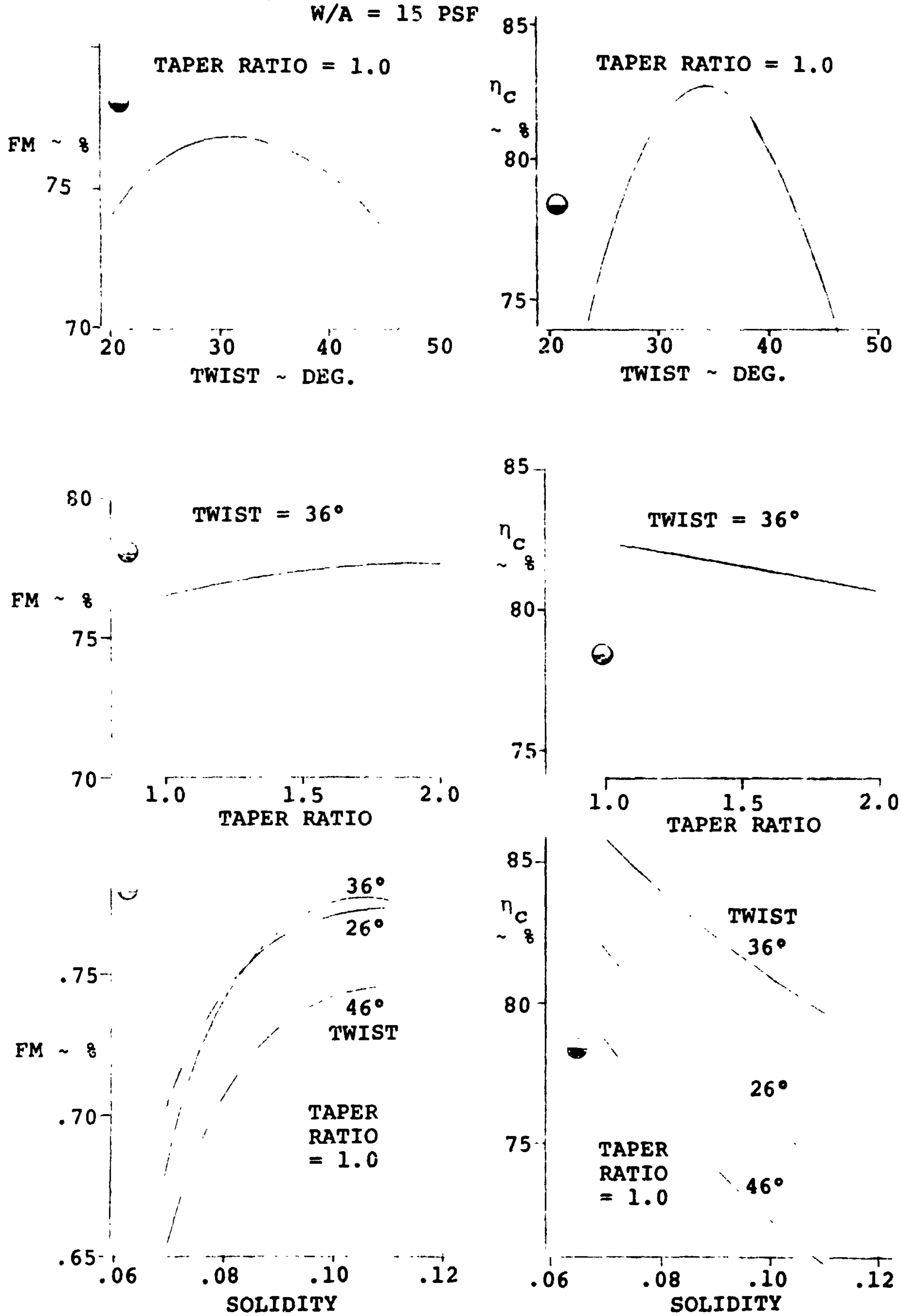

FIGURE 3.13. TILT ROTOR - ROTOR DESIGN STUDY.

NASA 1985 COMMERCIAL VTOL STUDY
TILT ROTOR

ROTOR TRADE STUDY

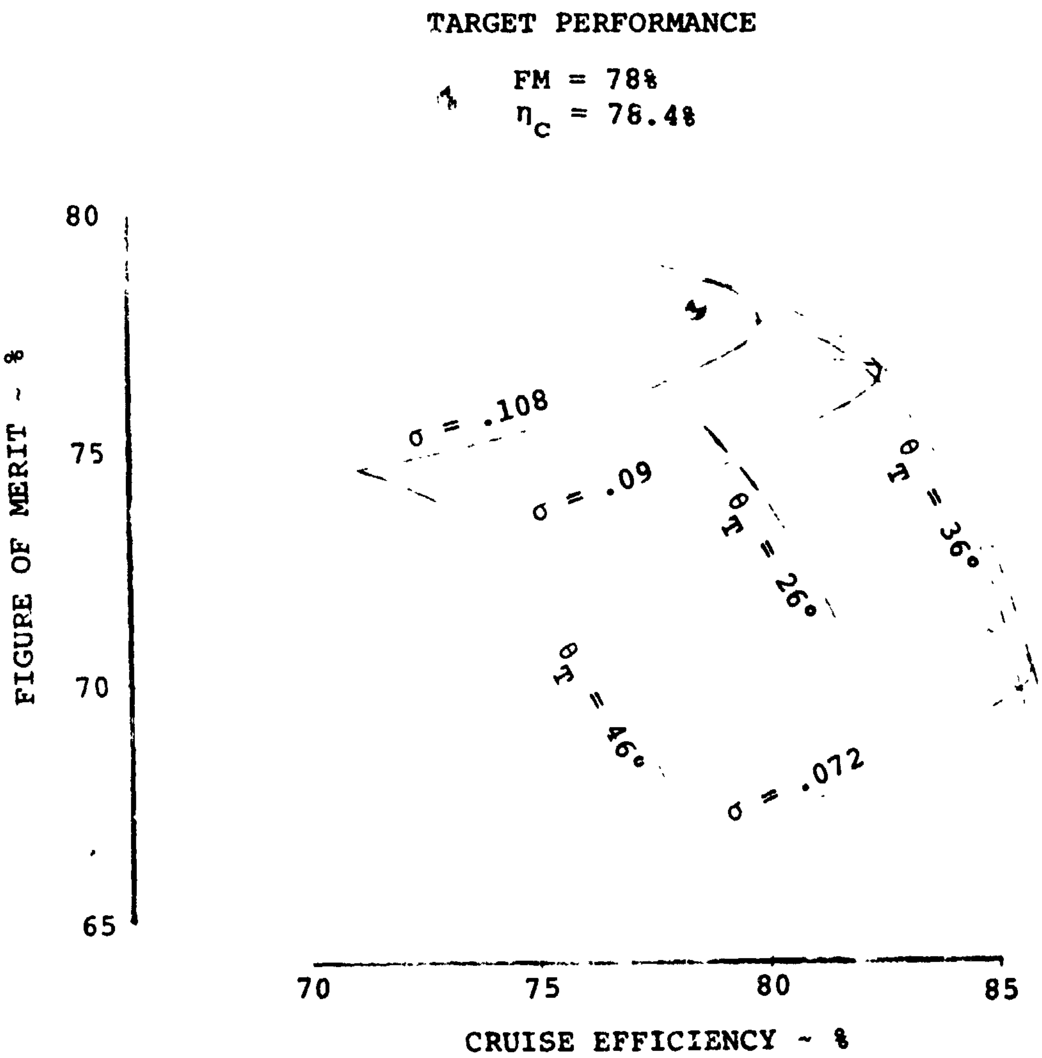

FIGURE 3.14. TILT ROTOR - ROTOR MAXIMUM PERFORMANCE ENVELOPE.

100 PASSENGER TILT ROTOR

EFFECT OF ROTOR PERFORMANCE AND DESIGN ON AIRCRAFT SIZE

V_{TIP} = 775 FPS W/A = 15.0 PSF

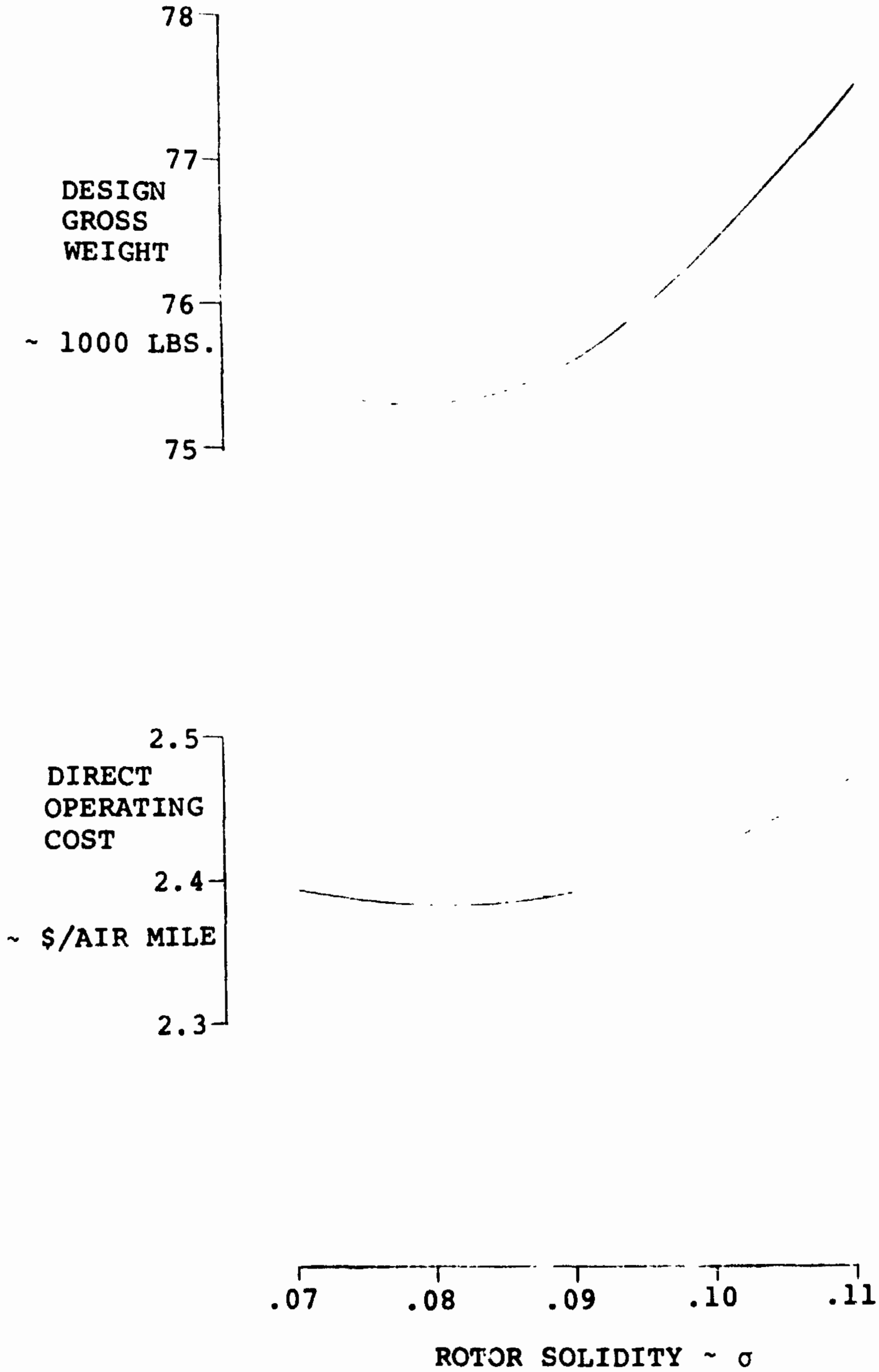

FIGURE 3.15. EFFECT OF ROTOR PERFORMANCE AND DESIGN ON AIRCRAFT SIZE.

in Figure 3.16 compared with existing aircraft and a tilt rotor trend line derived from previous tilt rotor design studies. The current drag estimates are consistent with those trends.

Engine Performance Tilt Rotor

The engines selected for the study was the AVCO Lycoming LTC4V-1 engine. This engine has an uninstalled engine rating of 5,000 SHF and a dry weight of 750 pounds. This power to weight ratio of .15 met the NASA criteria. The SFC of the engine was .418 at sea level standard, was less than the NASA criteris of .42 at takeoff power at sea level 90 degrees F. The aircraft design takeoff ambient, therefore, the fuel flow were adjusted to comply with the design criteria. Figures 3.17 and 3.18 give the referred installed performance of this engine used throughout this study as a function of turbine inlet temperature and flight Mach number.

Referred power is $\dfrac{SHP/\delta\sqrt{\theta}}{SHP^*}$

Referred fuel flow is $\dfrac{W_f/\delta\sqrt{\theta}}{SHP^*}$

Referred compressor speed is $\dfrac{N_I/\sqrt{\theta}}{N_1^*}$

Referred power turbine speed is $\dfrac{N_{II}/\sqrt{\theta}}{N_{II}^*}$

The installation factors applied included inlet and exhaust losses and a 1% compressor bleed for air conditioning and pressurization. Accessory horsepowers of 150 SHP total are

ITEM	DRAG AREA f_e - FT^2
FUSELAGE	10.3914
WING	7.3627
VERTICAL TAIL	2.2474
HORIZONTAL TAIL	2.5998
ROTOR NACELLE	1.2946
ENGINE NACELLE	2.6573
MISCELLANEOUS	
OIL COOLER MOMENTUM LOSS	.3750
AIR CONDITIONING	.5000
TRIM	.0640
TOTAL DRAG AREA	27.4922

TABLE 3.11. TILT ROTOR DRAG SUMMARY.

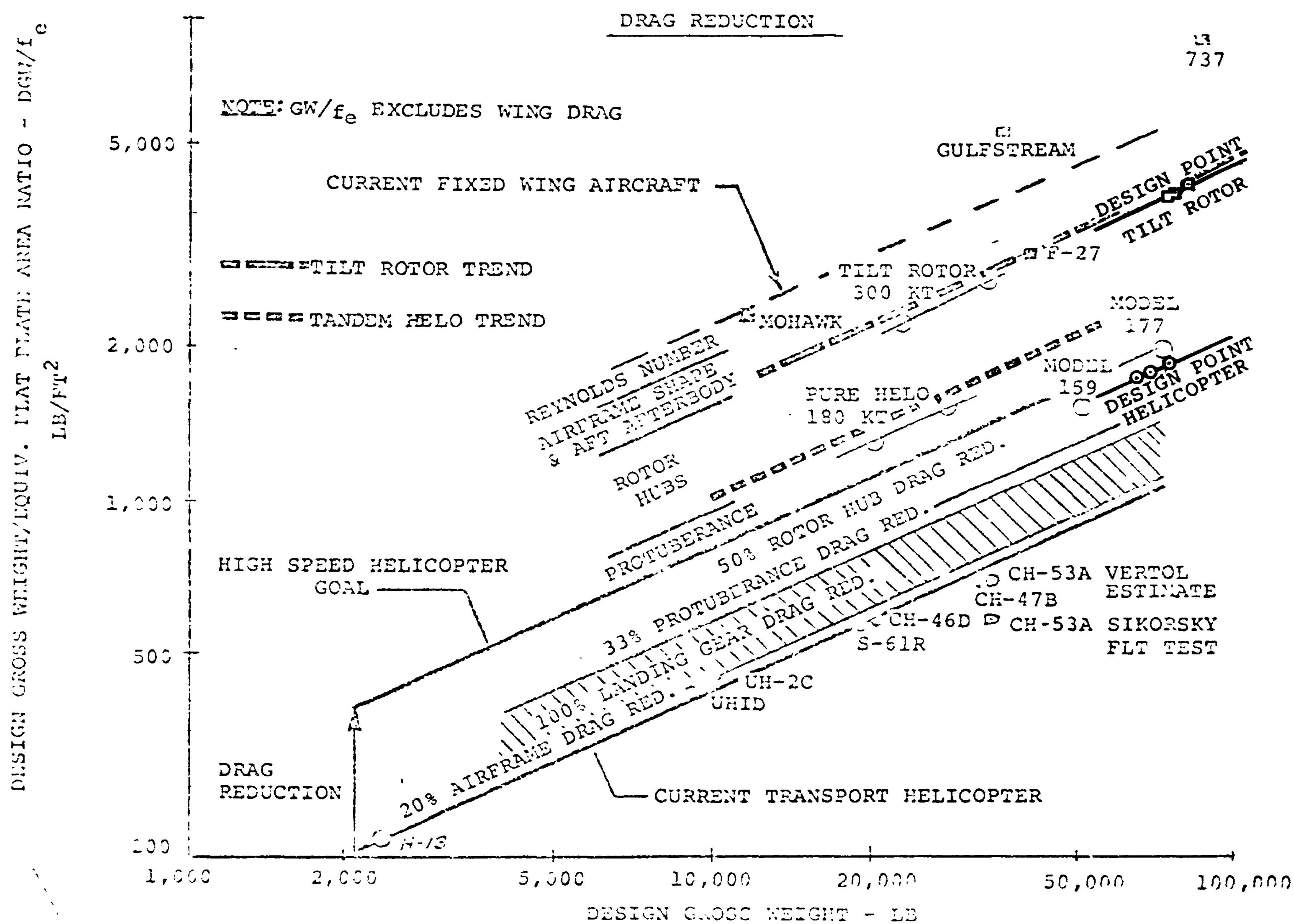

FIGURE 3.16. DRAG TREND COMPARISON.

deducted during aircraft performance calculations and are, therefore not included in the data of Figures 3.18 and 3.19.

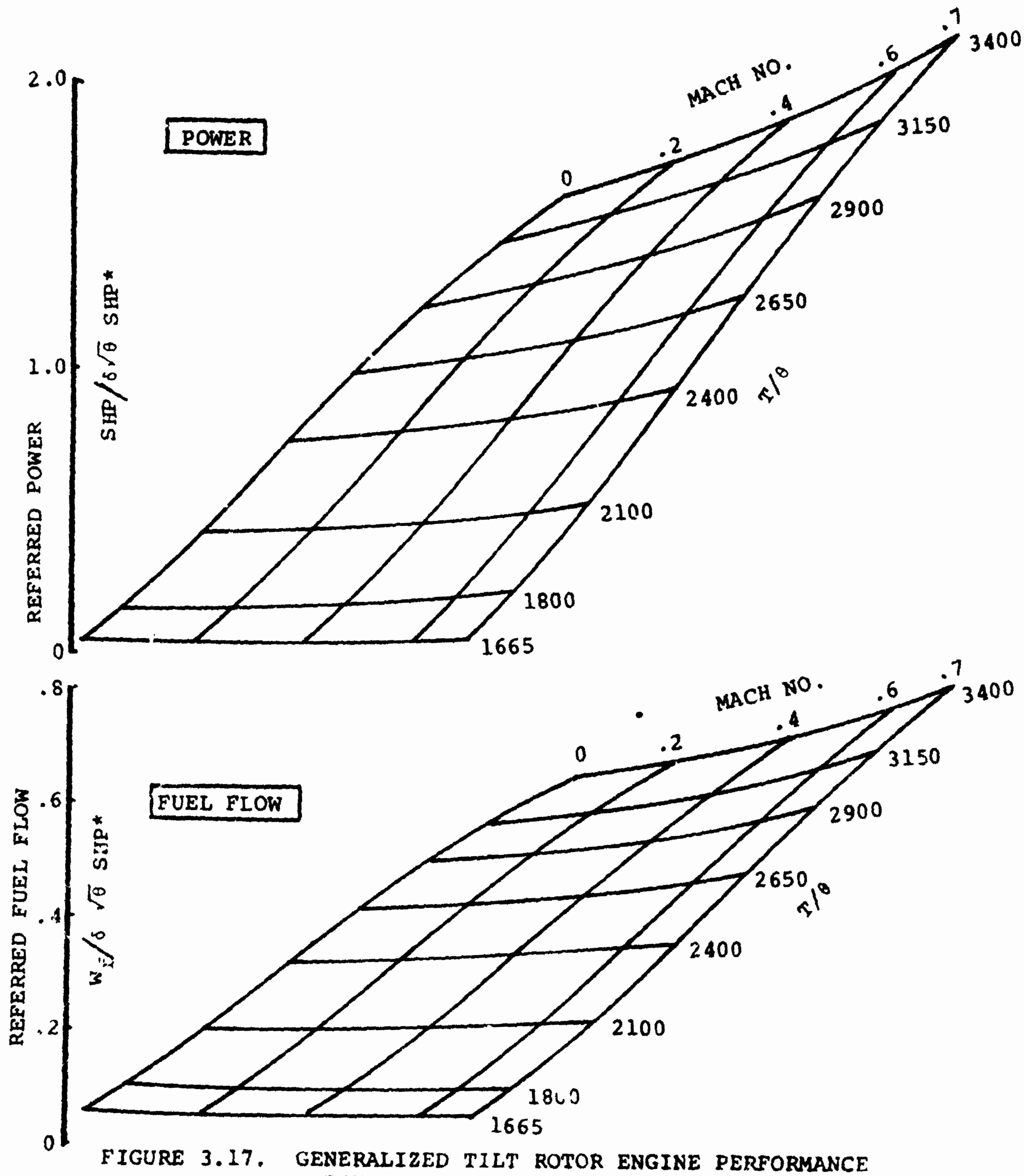

FIGURE 3.17. GENERALIZED TILT ROTOR ENGINE PERFORMANCE - POWER AND FUEL FLOW.

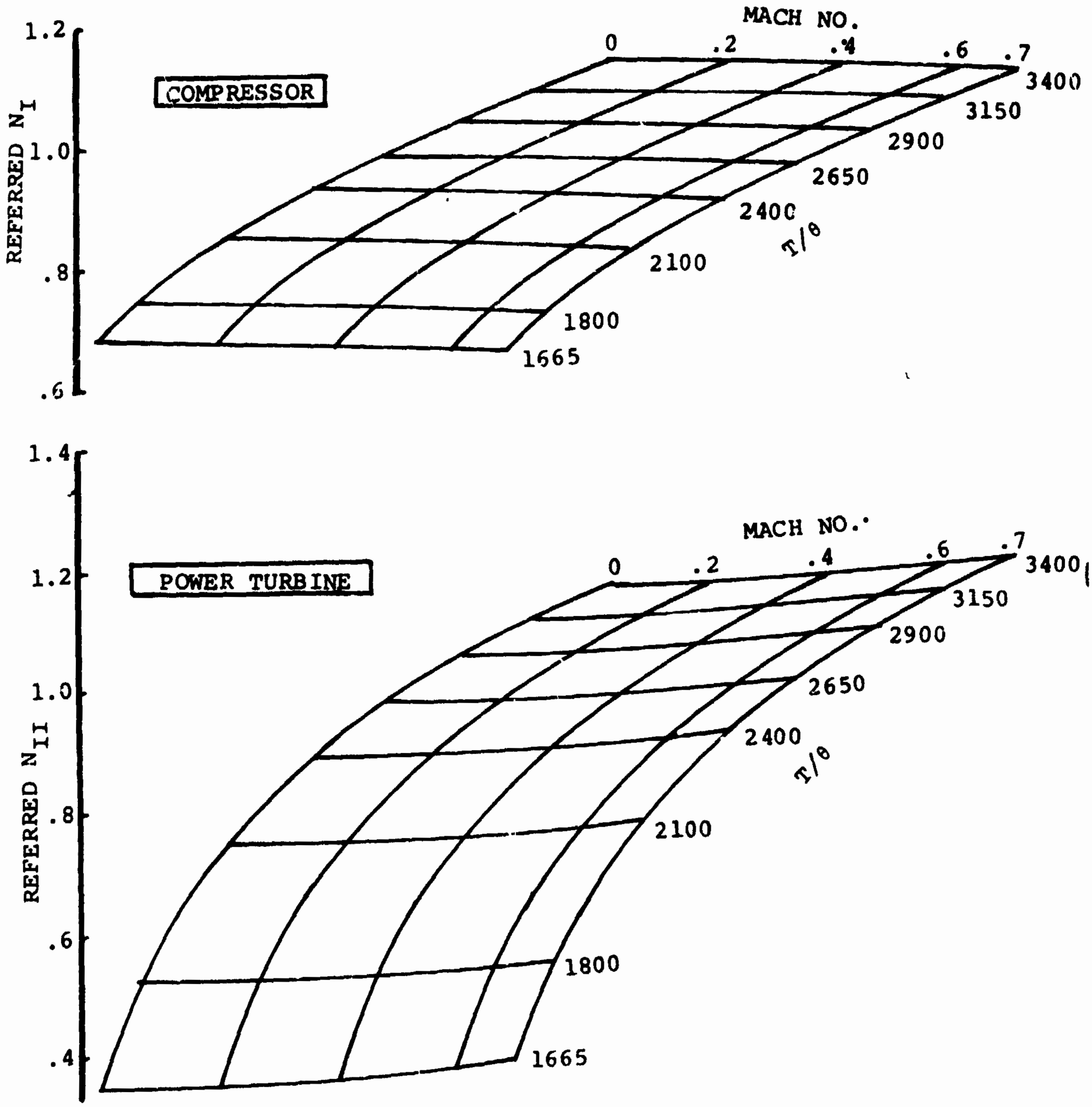

FIGURE 3.18. GENERALIZED TILT ROTOR ENGINE PERFORMANCE - COMPRESSOR AND POWER TURBINE SPEED.

3.2 WEIGHTS

The weights of the six configurations are summarized in Tables 3.12 and 3.13.

Weight trade studies leading to the selection of the baseline configurations were accomplished using computerized weight prediction programs. VASCOMP, sized and weighed the tilt rotor configurations. The HESCOMP helicopter program analyzed the helicopter type configurations. These sizing programs include a weights subroutine which automatically computes subsystem weight changes resulting from variations in the configuration size, flight envelope, payload, etc. They provide a consistent method for rapidly estimating the aircraft's operational weight empty and gross weight. The program divides the weight empty into three groups: propulsion, structures and flight controls. Weight trends are programmed for each group which compute their respective weights. These are then combined with weight input values of fixed useful load, fixed equipment and payload to determine the weight of the fuel available for a given gross weight and payload. The weight input values are determined from specific mission requirements and/or specified equipment lists. A flow chart for the weight trend subroutine is shown in Figure 3.19.

The weight trends were developed at Vertol from statistical and semianalytical data of existing aircraft. They combine geometric, design and structural parameters into an accurate weight prediction tool. Examples of the weight trends for

the major weight groups are presented in Figures 3.20 through 3.28.

The trends include sufficient design parameters to account for the major design features associated with each of the study configurations.

In order to provide comparisons of the design points with the statistical data the assumptions for weight reduction due to advanced composite materials have been removed in Figures 3.20 to 3.28.

The flight control trend, for example, is divided into six groups, which ensures that a weight allowance is included for all the major control items and special features. It includes:

- Cockpit controls
- Rotor controls
- Fixed-wing controls (includes type and number of control surfaces)
- Systems and hydraulics
- Tilt mechanism (includes tilting nacelle or wing mechanism)
- SAS and mixing (integrates airplane and helicopter controls).

The rotor group weight trends, Figures 3.20 and 3.22 includes parameters which considers number of rotors and blades, type of system (rigid, articulated, teetering, etc.) tipspeed, etc.

BOEING VERTOL COMPANY

WEIGHT SUMMARY - PRELIMINARY DESIGN
MIL-STD-1374

	DESIGN POINT		+5 PNdB		-5 PNdB	
	KILOGRAMS	POUNDS	KILOGRAMS	POUNDS	KILOGRAMS	POUNDS
WING	1960.9	4323	1932.7	4261	2018.0	4449
ROTOR	2379.5	5246	2325.1	5126	2566.0	5657
TAIL	636.8	1404	618.7	1364	695.8	1534
SURFACES	636.8	1404	618.7	1364	695.8	1534
ROTOR						
BODY	3853.2	8495	3849.2	8486	3863.7	8518
BASIC						
SECONDARY						
ALIGHTING GEAR GROUP	1356.2	2990	1328.6	2929	1445.6	3187
ENGINE SECTION	430.0	948	416.8	919	504.8	1113
PROPULSION GROUP	4751.8	10476	4225.2	9315	6145.2	13548
ENGINE INST'L	1184.3	2611	1148.0	2531	1391.6	3068
EXHAUST SYSTEM *						
COOLING						
CONTROLS *						
STARTING *						
PROPELLER INST'L	*367.4	*810	*356.1	*785	*431.4	951
LUBRICATING *						
FUEL	99.3	219	94.3	208	105.2	232
DRIVE	3100.8	6836	2626.7	5791	4217.0	9297
FLIGHT CONTROLS	1835.2	4046	1818.0	4008	1979.5	4364
AUX. POWER PLANT	288.5	636	288.5	636	288.5	636
INSTRUMENTS	191.9	423	191.9	423	191.9	423
HYDR. & PNEUMATIC	308.4	680	308.4	680	308.4	680
ELECTRICAL GROUP	378.3	834	378.3	834	378.3	834
AVIONICS GROUP	293.9	648	293.9	648	293.9	648
ARMAMENT GROUP						
FURN. & EQUIP. GROUP	3273.6	7217	3273.6	7217	3273.6	7217
ACCOM. FOR PERSON.						
MISC. EQUIPMENT						
FURNISHINGS						
EMERG. EQUIPMENT						
AIR CONDITIONING	612.3	1350	612.3	1350	612.3	1350
ANTI-ICING GROUP	254.0	560	254.0	560	254.0	560
LOAD AND HANDLING GP.						
WEIGHT EMPTY	22804.7	50276	22115.2	48756	24819.6	54718
CREW	299.4	660	299.4	660	299.4	660
TRAPPED LIQUIDS	52.2	115	52.2	115	52.2	115
ENGINE OIL	59.9	132	59.9	132	59.9	132
CREW ACCOMMODATIONS	68.0	150	68.0	150	68.0	150
EMERGENCY EQUIPMENT	23.6	52	23.6	52	23.6	52
PASSENGER ACCOMMO.	415.5	916	415.5	916	415.5	916
PASSENGERS (100)	8164.6	18000	8164.6	18000	8164.6	18000
FUEL	2017.6	4448	2012.1	4436	2240.3	4939
GROSS WEIGHT	33905.4	74749	33210.5	73217	36143.0	79682

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TABLE 3.12. DESIGN POINT TILT ROTOR - WEIGHT SUMMARY.

BOEING VERTOL COMPANY

WEIGHT SUMMARY - PRELIMINARY DESIGN

MIL-STD-1374

	DESIGN POINT		+5 PNdB		-5 PNdB	
	KILOGRAMS	POUNDS	KILOGRAMS	POUNDS	KILOGRAMS	POUNDS
WING						
ROTOR	3029.1	6678	2745.1	6052	3729.9	8223
TAIL						
SURFACES						
ROTOR						
BODY	2950.1	6504	2840.4	6262	2996.9	6607
BASIC						
SECONDARY						
ALIGHTING GEAR GROUP	1218.8	2687	1194.8	2634	1346.3	2968
ENGINE SECTION	222.7	491	222.7	491	222.7	491
PROPULSION GROUP	4401.2	9703	4211.6	9285	5705.3	12578
ENGINE INST'L	997.9	2200	949.4	209.3	1191.1	2626
EXHAUST SYSTEM *						
COOLING						
CONTROLS *						
STARTING *						
PROPELLER INST'L	*82.6	*182	*78.5	*173	*98.4	*217
LUBRICATING *						
FUEL	219.1	483	241.3	532	241.3	532
DRIVE	3101.6	6838	2942.4	6487	4174.4	9203
FLIGHT CONTROLS	1031.9	2275	718.5	1584	1733.6	3822
AUX. POWER PLANT	288.5	636	288.5	636	288.5	636
INSTRUMENTS	191.9	423	191.[illegible]	423	191.9	423
HYDR. & PNEUMATIC	308.4	680	308.4	680	308.4	680
ELECTRICAL GROUP	378.3	834	378.3	834	378.3	834
AVIONICS GROUP	293.9	648	293.9	648	293.9	648
ARMAMENT GROUP						
FURN. & EQUIP. GROUP	3206.9	7070	3206.9	7070	3206.9	7070
ACCOM. FOR PERSON.						
MISC. EQUIPMENT						
FURNISHINGS						
EMERG. EQUIPMENT						
AIR CONDITIONING	521.6	1150	521.6	1150	521.6	1150
ANTI-ICING GROUP	181.4	400	181.4	400	181.4	400
LOAD AND HANDLING GP.						
WEIGHT EMPTY	18224.8	40179	17304.0	38149	21105.5	46530
CREW	299.4	660	299.4	660	299.4	660
TRAPPED LIQUIDS	52.2	115	52.2	115	52.2	115
ENGINE OIL	59.9	132	59.9	132	59.9	132
CREW ACCOMMODATIONS	68.0	150	68.0	150	68.0	150
EMERGENCY EQUIPMENT	7.3	16	7.3	16	7.3	16
PASSENGER ACCOMMO.	415.5	916	415.5	916	415.5	916
PASSENGERS (100)	8164.6	18000	8164.6	18000	8164.6	18000
FUEL	3178.3	7007	3494.9	7705	3496.2	7708
GROSS WEIGHT	30469.9	67175	29865.7	65843	33668.6	74227

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FORM 26391

TABLE 2-17

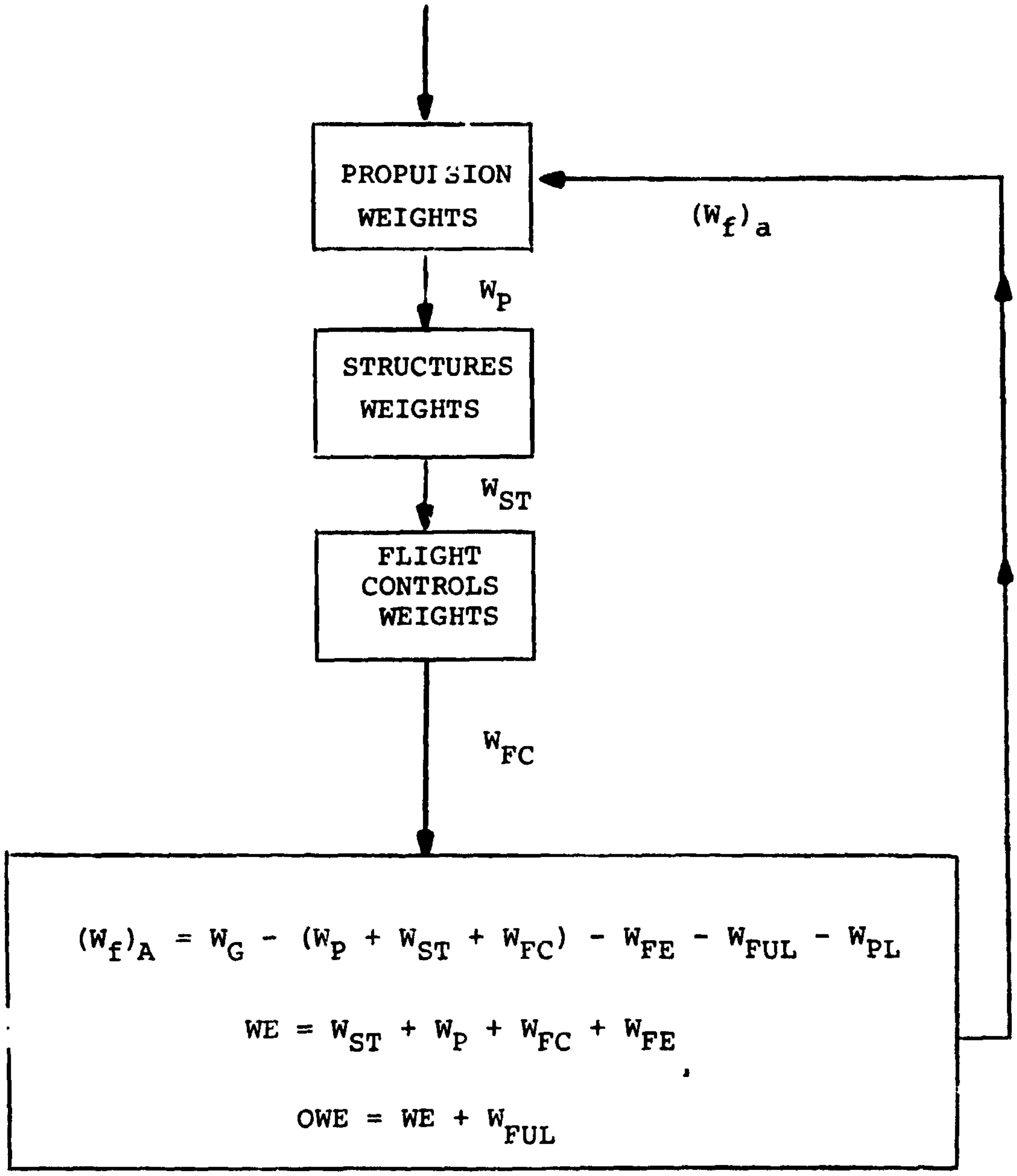
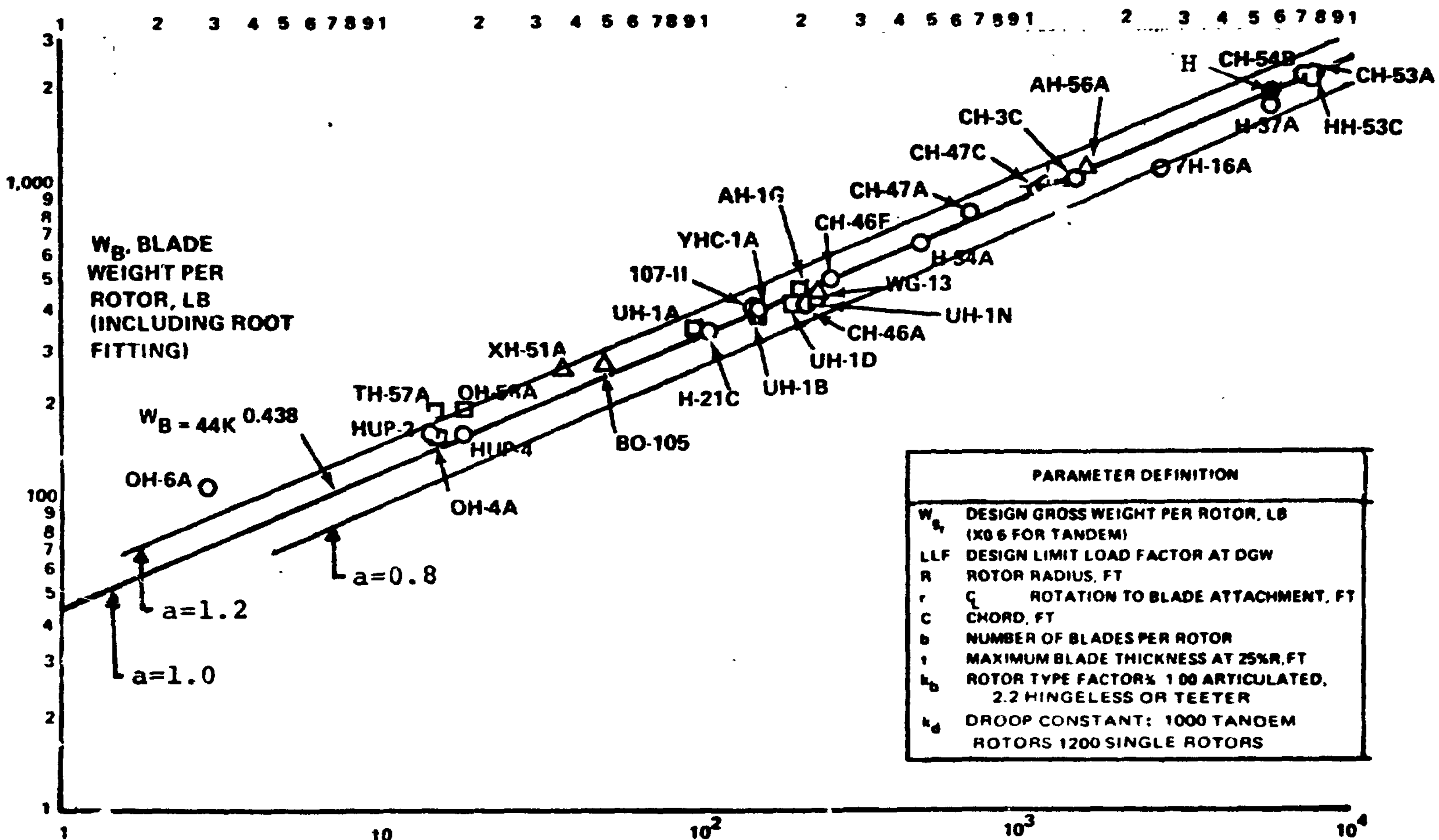


FIGURE 3.19. WEIGHT TRENDS SUBROUTINE, FLOW CHART.

Weight trends similar to the one shown in Figure 3.23 were used to predict the weight of configurations designed around airplane type fuselage structure as in the case of the tilt rotor aircraft. Figure 3.24 describes the trend which was used in conjunction with helicopter-type fuselage structure where tail booms, tail rotors or tail fans are used.

Drive system weight is determined by multiplying the constant (K) by a simple torque expression as indicated by the overall drive system weight trend shown in Figure 3.25. Determination of the constant is the end result of a detailed box-by-box analysis of the drive system configuration. The semianalytical method calculates the weight of each gear set. It includes the effects of Hertz stress, gear ratio, bearing support, number of gears in a stage, and external or structural supports. The drive shafting weight is determined independent of the box weight and includes parameters which consider the number of shaft sections and transmitted torque.

Wing and tail weight trends are shown in Figures 3.26 to 3.28. The trend constants "K" are primary inputs to the computer programs. Selection of the constants depend on the type of aircraft being configured - helicopter, compound, tilt rotor, etc., material, and level of technology. Peculiar design loads and stiffness requirements and special design features such as folding rotor blades, tilting nacelles, shrouded tail fans, etc. are studies individually and inputed as a variation of the constant or included as a direct weight input in the incremental group weight section of the VASCOMP



$$K = \frac{W_{g_R}}{10^4} \; LLF \; \frac{R^2}{100} \; \frac{(R-r)}{10} \; b\,C\,k_b \left[\frac{R^{1.6}}{k_d\,t}\right]$$ (USE [TERM] IF GREATER THAN 1.00

FIGURE 3.20. ROTOR BLADE WEIGHT TREND HELICOPTERS.

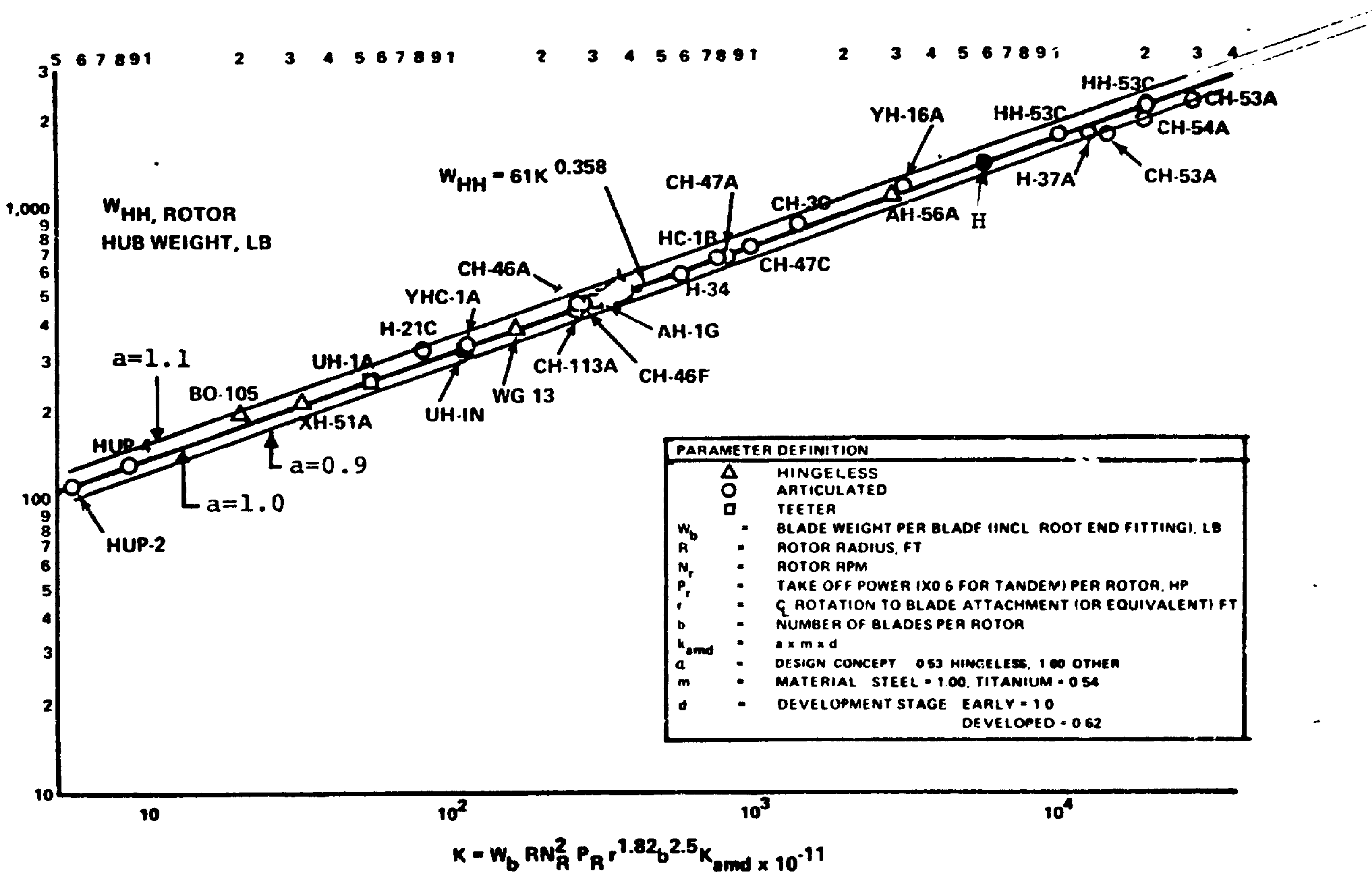


FIGURE 3.21 . ROTOR HUB AND HINGE WEIGHT TREND HELICOPTERS.

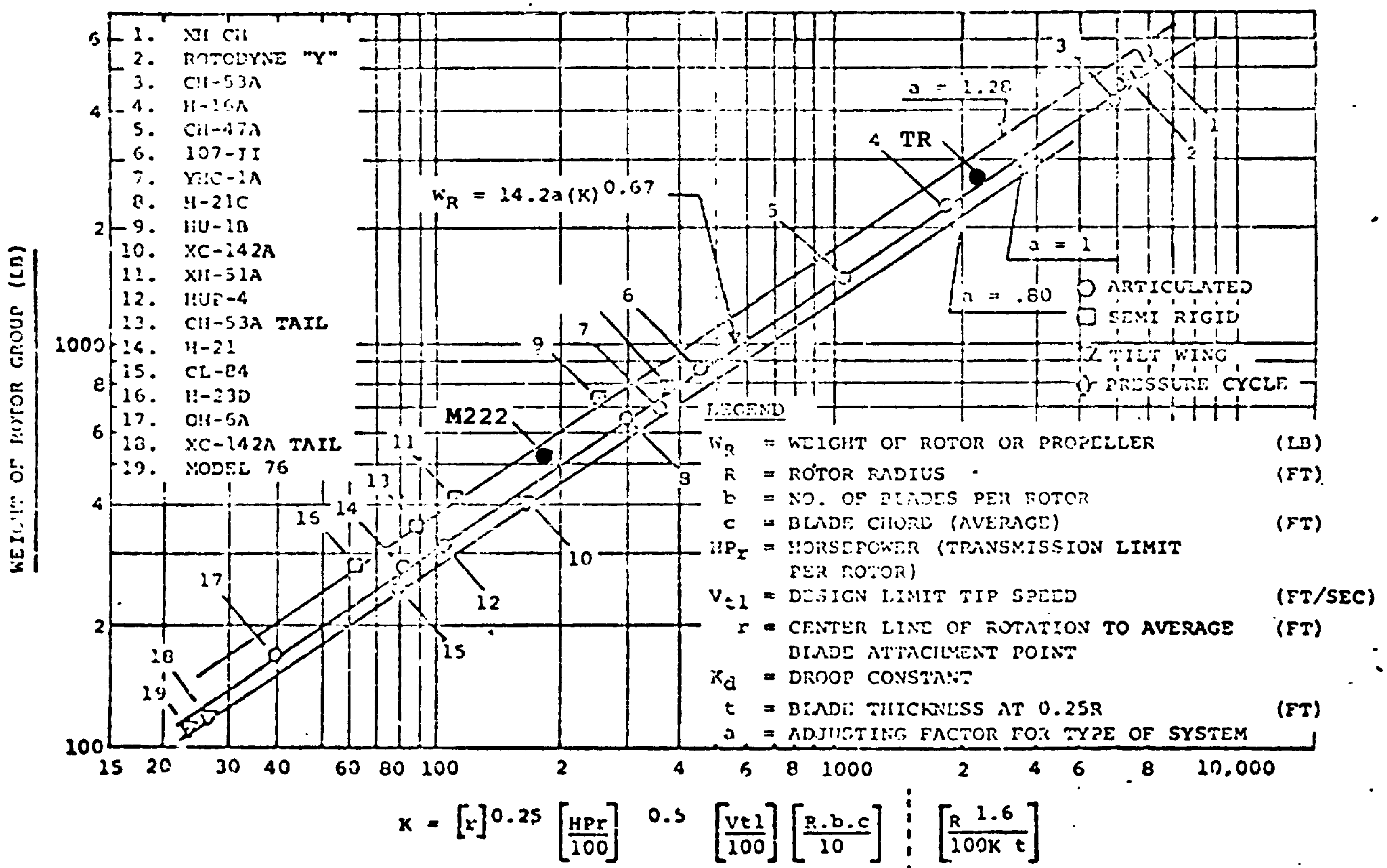
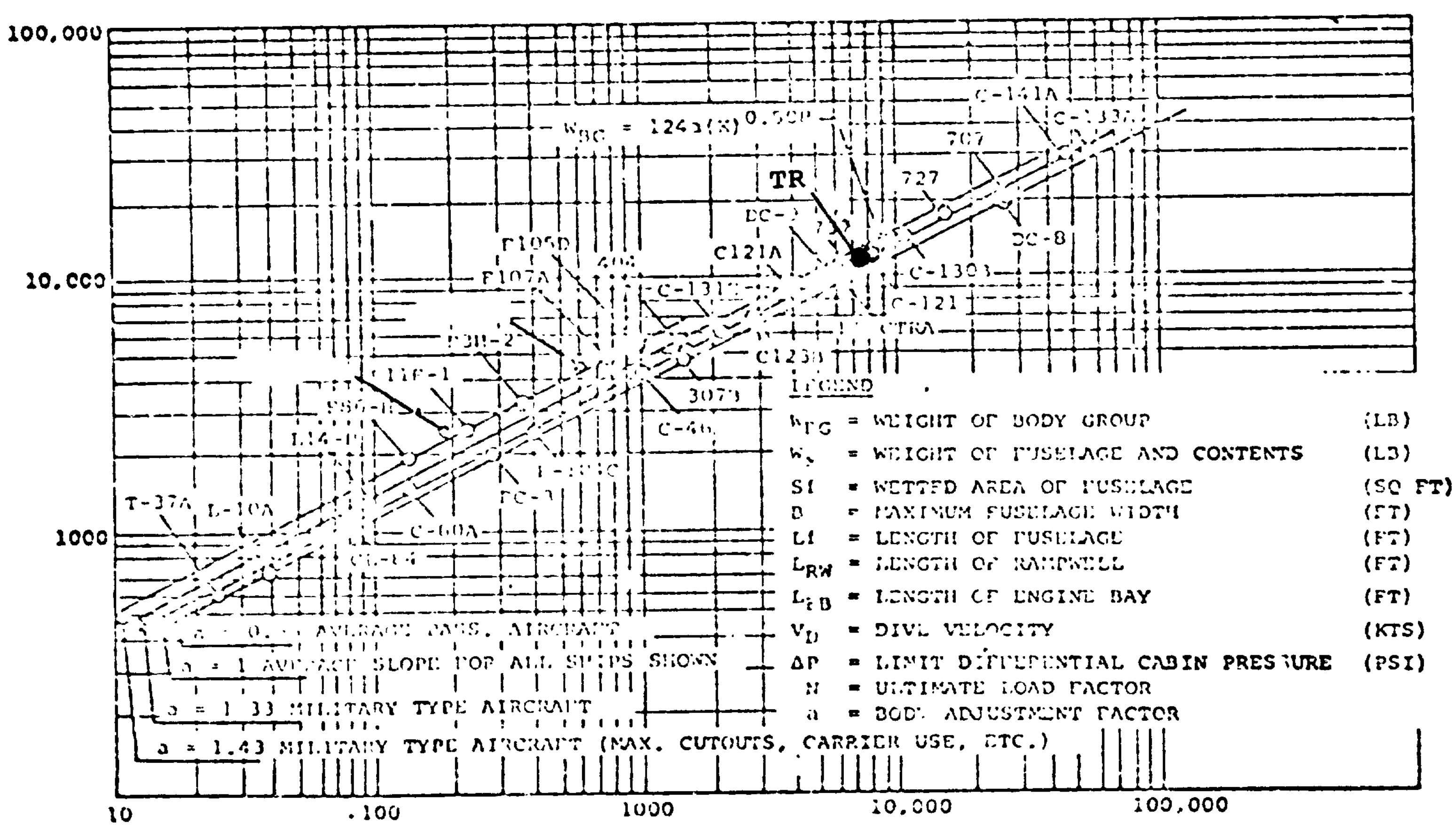


FIGURE 3.22 . ROTOR GROUP WEIGHT TREND TILT ROTOR.



$$K = \left[\frac{W_x}{10^4}\right]^{0.7} \left[\frac{Sf}{10^3}\right] B(Lf + L_{RW})^{0.5} \left[\log_{10} V_D\right] (\Delta P + 1)(N)^{0.3}$$

FIGURE 3.23 . AIRPLANE BODY GROUP WEIGHT TREND

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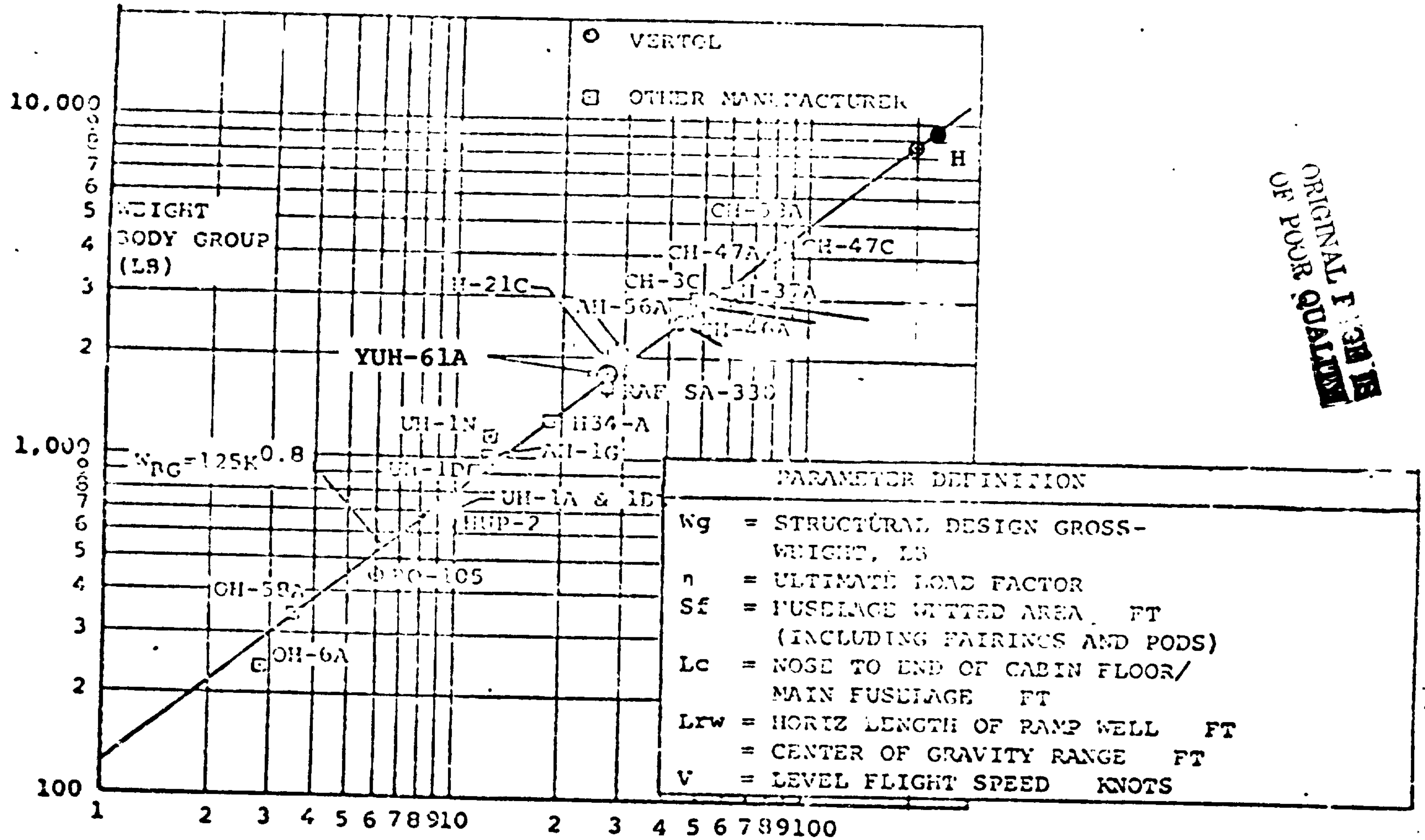

$$K = \left[\frac{W_G}{10^4}\, n\, \frac{S_f}{10^3}\, (L_c + L_{rw} + \Delta)\right]^{0.5} \text{Log } V_{max}$$

FIGURE 3.24. HELICOPTER BODY WEIGHT TRENDS

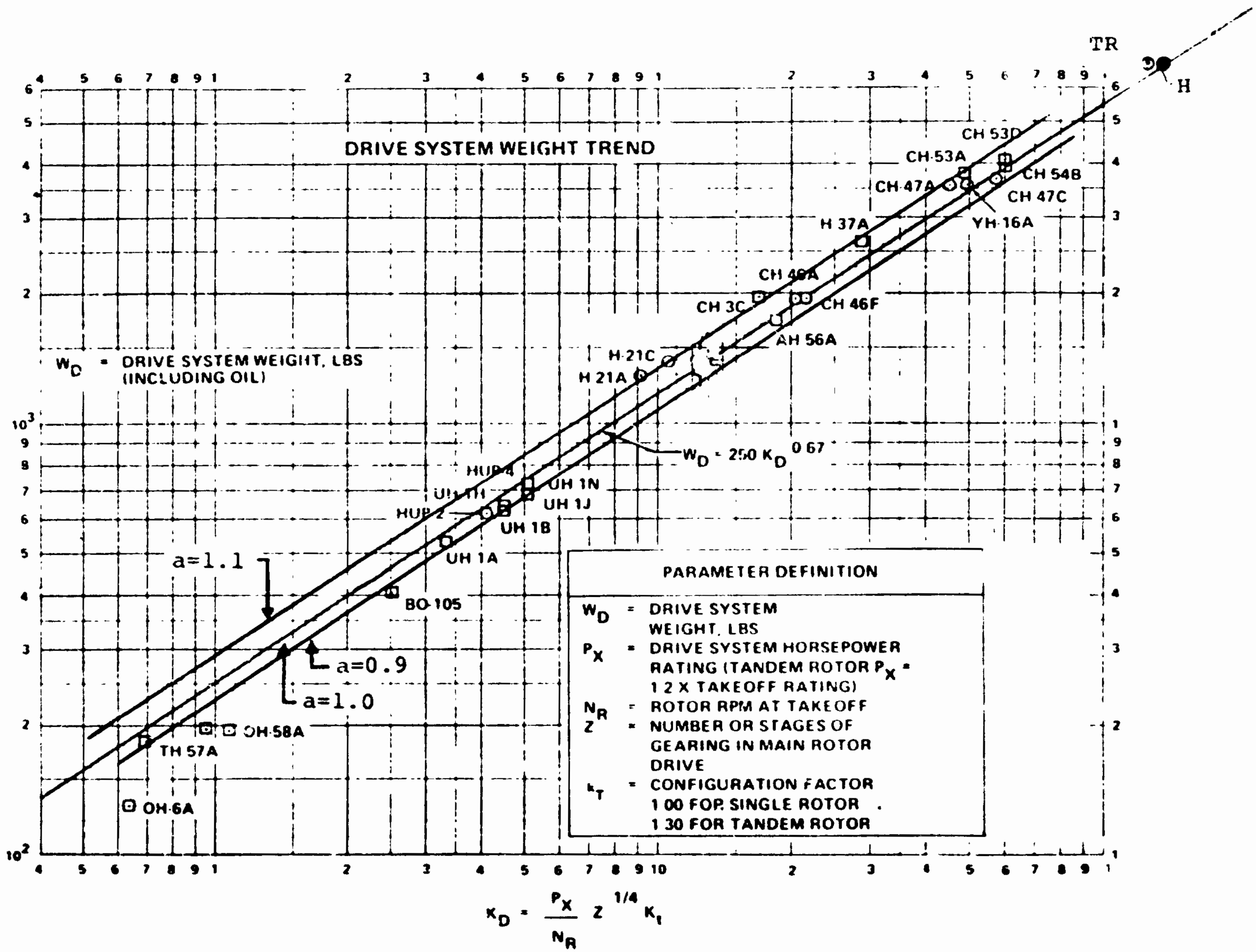

FIGURE 3.25. DRIVE SYSTEM WEIGHT TREND - PRIMARY AND AUXILIARY.

weights input form.

Current Vertol CH-46, CH-47 and HLH contracts for tandem helicopter and the detailed design of the Model 222 Tilt Rotor Research Aircraft provide the data bank used for selecting the weight constants. In order to show substantiation of these weights, the Design Point Helicopter and the Design Point Tilt Rotor configurations were chosen and evaluated, using refined prediction methods and parameters. These substantiating calculations are included on Page . The computerized weight prediction programs were based on the assumptions discussed below.

Limit Load Factor

The limit load factors at mission gross weights are:

1. Helicopters, 3.5 from FAR, Part 29.
2. Tilt rotor, 2.5 from FAR, Part 25.

$$L.L.F. = 2.1 + \frac{24,000}{W + 10,000}$$

"L.L.F. SHALL BE NO LOWER THAN 2.5, BUT NEET NOT BE HIGHER THAN 3.8."

W = MAXIMUM DESIGN GROSS WEIGHT.

In the gross weight ranges of these tilt rotor aircraft the limit load factor did not exceed 2.5 thus 2.5 was established.

Advance Materials for 1985 Operational Time Period

From the Study Guidelines, Paragraph 4.5, the following is quoted: "The Contractor shall assume that the airframe structural wei ght will be reduced approximately 25% by the use of

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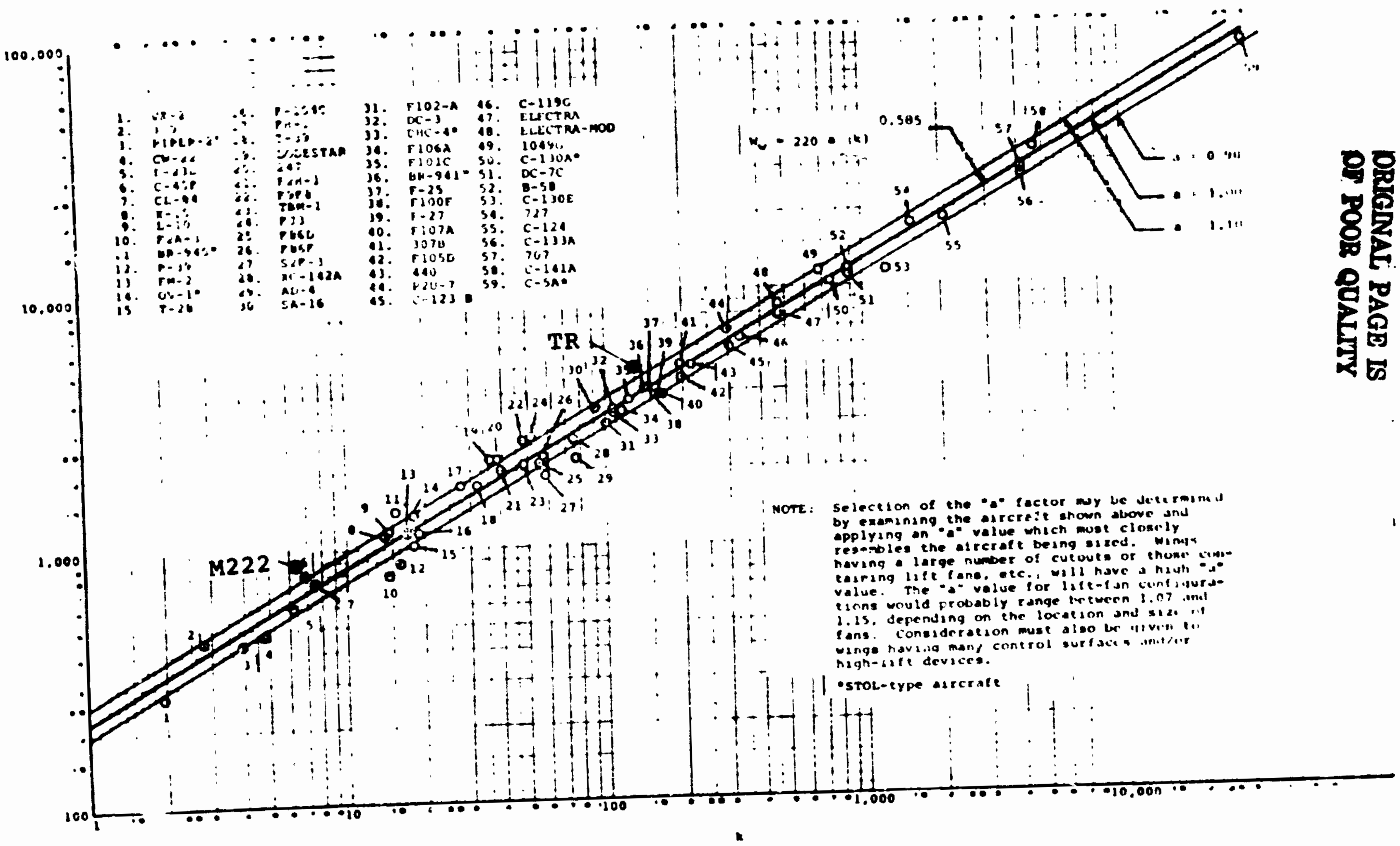


FIGURE 3.26 . WING WEIGHT TREND.

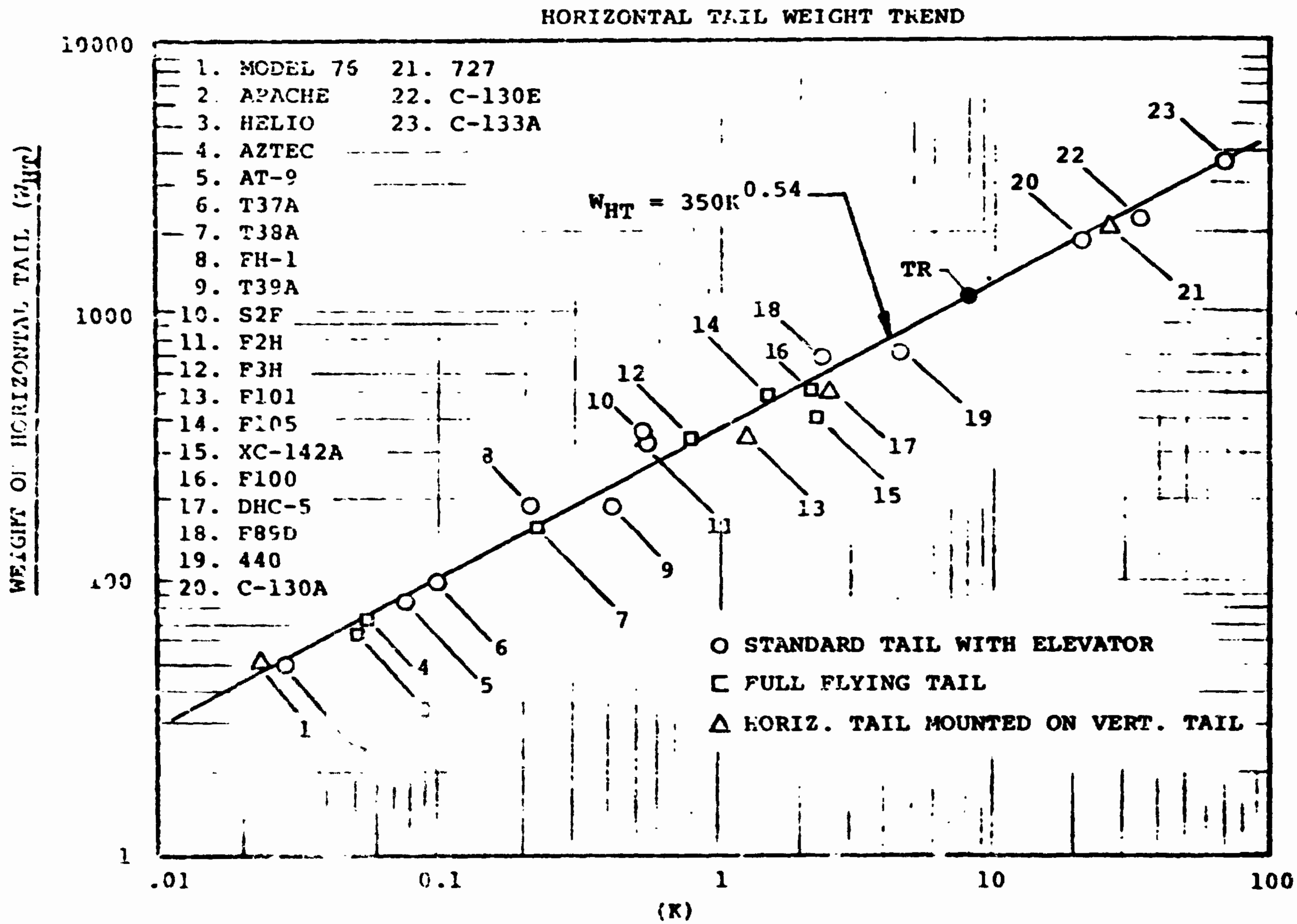


FIGURE 3.27. HORIZONTAL TAIL WEIGHT TREND.

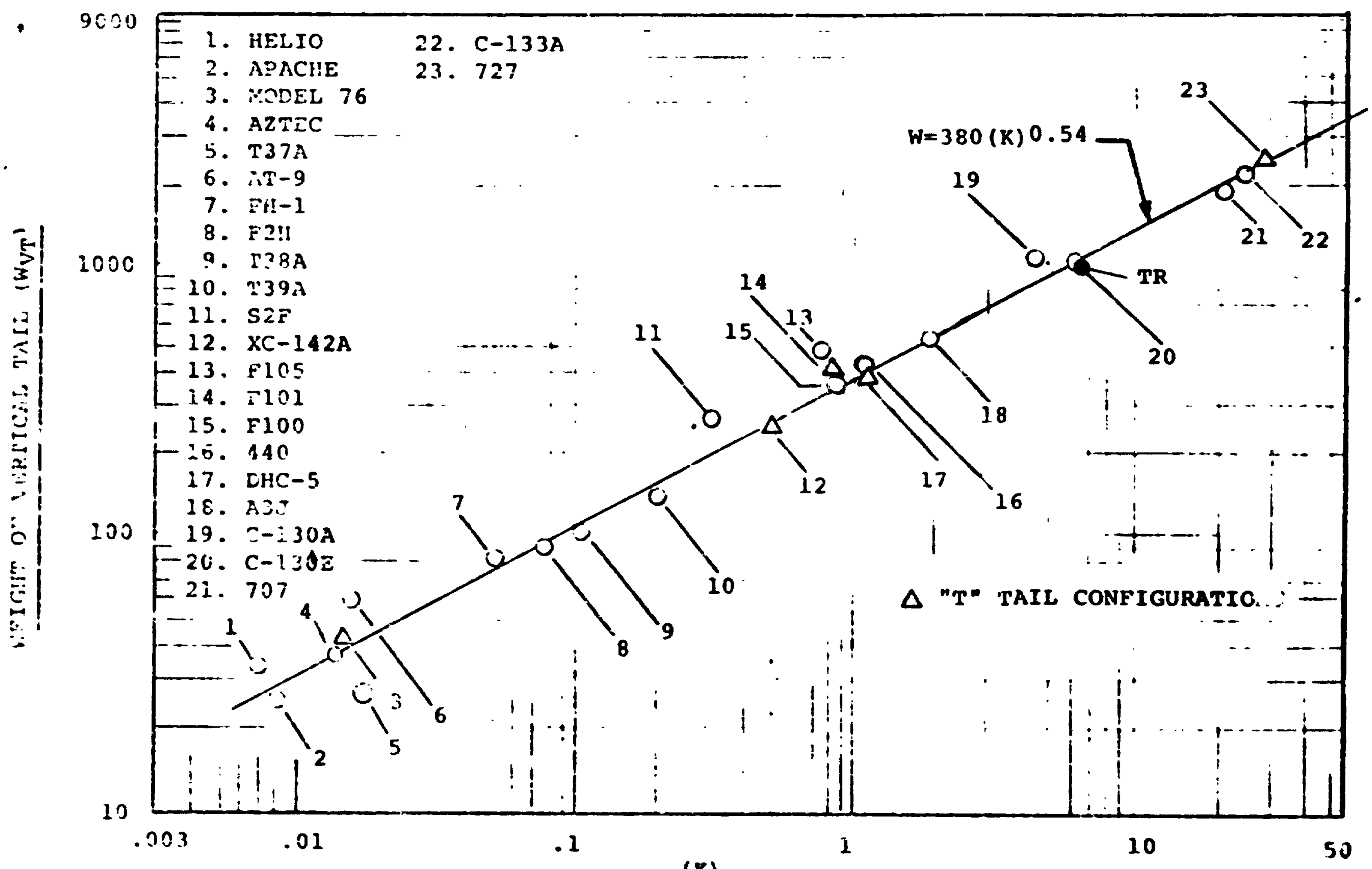


FIGURE 3.28. VERTICAL TAIL WEIGHT TREND.

composite materials." Boeing Vertol has chosen to distribute this weight as follows:

	REDUCTION (%)	
	TILT ROTOR	HELICOPTER
WING	30.2	0
TAIL	30.2	36.1
BODY	30.2	36.1
LANDING GEAR	0	0
ENGINE SECTION	30.2	0
EQUIVALENT TOTAL	25.0	25.0

Wing

The wing weight of the tilt rotor was based on that of the Boeing Vertol Model 222 tilt rotor aircraft. This wing was designed by Grumman Aircraft Company under direction of Boeing Vertol and the weights calculated in detail. Adjustments have been made for advanced materials. A comparison of the design point wing weight, with no composite material assumptions, with the weight trend curves is shown in Figure 3.26.

Rotor

Rotors of both the helicopter and tilt rotor have titanium hubs and root end fittings and fiberglass blades. The Model 222 rotor is used as a basis for the tilt rotor with adjustments made for titanium hub and root end fittings in lieu of steel.

The helicopter rotors are based on average values on the trend curves.

Tail Surfaces

Tail surface weights were based on trends using statistical data from similar aircraft. Adjustments have been made for advanced materials.

Body

Weights of the bodies were based on trends using statistical data of other aircraft. Adjustments have been made for advanced materials. The tilt rotor body is pressurized for 7,000 feet at 14,000 feet. The helicopter body is not pressurized.

Alighting Gear

The alighting gear of both aircraft are retractable, designed for a sink speed of 5 feet per second. A value of 4% gross weight has been selected.

Engine Section

The tilt rotor engine section was based on that of the Model 222, 52% of the engine weight.

The helicopter engine section weight was determined from layouts. All have been adjusted for the use of advanced materials.

Engines

The engine weights were based on rubberized LTC-4V-1 engines at 0.1575 pounds per horsepower.

Engine Installation

Engine installation consists of exhaust systems, propeller spinners, engine controls, starting system, and engine lubrication system. The input values for the computer are

in percent of engine weight and are 8.3% for the helicopter and 31% for the tilt rotor aircraft.

The helicopter value was based on that of the Vertol CH-47, the tilt rotor value was based on the Vertol Model 222.

Fuel System

The fuel system weights for the tilt rotor were based on the Boeing 737-200. Tanks are in the wing. Since the helicopter tanks are located in the body beneath the floor, they have been assumed to be crash resistant.

Weight inputs in the computer are in the form of pounds per pound of fuel.

Drive System

The tilt rotor drive system weight was based on that of the Vertol Model 222. The helicopter weight was based on the values of similar tandem rotor systems on the trend curve.

Flight Controls

The flight control weights were based on Vertol Model 222 and typical tandem helicopter weights, reduced for fly-by-wire systems. The weight reductions as applied to these systems are:

Cockpit	29%
Rotor Upper Controls	0
Rotor System Controls	20%
Airplane Type Controls	20%
SAS	0
POD Tilting Mechanism	13%

Fixed Equipment

The fixed equipment weights were based primarily on the Boeing 737-200 and the Vertol CH-46, adjusted in some areas for weights quoted in the "Study Guidelines". Tables 3.14 and 3.15 summarize those used in these studies.

APU, Instruments, Electronics and Electrical

Paragraph 4.9 of the "Study Guidelines" quotes a weight of 1,200 pounds for these items, not including electrical generation. In comparing this to the Boeing 737-200, Boeing Vertol has assumed that this 1,200 pounds is an uninstalled weight.

		WEIGHT	
BOEING 737-200	TOTAL	EQUIPMENT	INSTALLATION
APU	830	308	522
INSTRUMENTS	552	323	229
ELECTRONICS	846	280	566
ELECTRICAL	712	712	---
TOTALS	2940	1623	1317

Using the above, it can be determined that the installation weight is 81% of the uninstalled weight.

$$\frac{1317}{1623} = 0.81$$

By applying this factor to the 1,200 pounds, the installation weight is 972 pounds. This and the electrical generation weights are shown separately in Tables 3.14 and 3.15.

A frowth factor (assuming constant performance and strength) of 1.9 for the helicopter and 2.1 for the tilt rotor have been

established. The curves in Figures 3.29 and 3.30 show the weight growth effect on these aircraft. If the 972 pounds of installation weight were not included, the gross weight of the helicopter would decrease from 67, 175 pounds to 65,328 pounds, the tilt rotor gross weight would decrease from 74,749 pounds to 72,708 pounds.

Hydraulics and Pneumatics

The hydraulics and pneumatics weights were established as 680 pounds based on the Boeing 737-200.

Furnishings and Equipment

Furnishings and equipment consist of Flight Deck Accommodations, Passenger Accommodations, Cargo Accommodations and Emergency Accommodations and are listed in Tables 3.19 and 3.20. They are based primarily on those of the Boeing 737-200, adjusted in certain areas to agree with weights quoted in the "Study Guidelines".

Air Conditioning

The helicopter air conditioning system is based on 11.5 pounds per passenger. The tilt rotor air conditioning system, including pressurization is based on 13.5 pounds per passenger.

Anti-Icing

Anti-icing weights for the helicopter is based on the Boeing Vertol CH-46 at 0.6% design gross weight.

Anti-icing weights for the tilt rotor are based on:

737-200 = 0.25% Gross Weight

CH-46 = $\frac{0.5\%}{0.75\%}$ Gross Weight

Useful Load

The useful loads weights (not including fuel) are shown in Tables 3.21 and 3.22. They are based on the Boeing 737-200, adjusted in certain areas for weights quoted in the "Study Guidelines".

Weight Substantiation

The weights leading to the selection of the configurations shown in this study were derived by using the computerized sizing and weight prediction programs, VASCOMP and HESCOMP.

Substantiation of these weights using weight prediction methods developed and improved by Boeing Vertol Weight Unit, are presented in this section of the report. The two design point aircraft were chosen as examples, see Tables 3.23 and 3.24.

	737-200 88 PASSENGERS Kg	737-200 88 PASSENGERS (Lbs)	50 PASSENGERS Kg	50 PASSENGERS (Lbs)	75 PASSENGERS Kg	75 PASSENGERS (Lbs)	100 PASSENGERS Kg	100 PASSENGERS (Lbs)
APU	139.7	308						
Instruments	146.5	323						
Electronics	127.0	280	544.2	1200*	544.2	1200*	544.2	1200*
Electrical	322.9	712						
Installation for Above	597.3	1317	440.8	972	440.8	972	440.8	972
Electrical Generation	167.3	369	167.3	369	167.3	369	167.3	369
Hydraulics & Pneumatics	391.8	864	176.9	390	251.7	555	308.4	680
Flight Deck Accommodations	266.2	587	257.6	568	257.6	568	257.6	568
Passenger Accommodations	2829.5	6239	1391.4	3068	2151.9	4745	2737.9	6037
Cargo Accommodations	278.0	613	72.6	160	108.8	240	145.1	320
Emergency Accommodations	164.6	363	58.0	128	62.6	138	65.8	145
Conditioning	539.7	1190	260.8	575	403.6	890	521.5	1150
Anti-Icing	96.1	212	102.0	225	147.3	325	181.4	400
TOTAL FIXED EQUIPMENT	6066.6	13,377	3471.6	7,655	4535.8	10,002	5370.0	11,841

*Quoted From Study Guideline

TABLE 3.14 . FIXED EQUIPMENT - HELICOPTER.

	737-200 88 PASSENGERS Kg	(Lbs)	50 PASSENGERS Kg	(Lbs)	75 PASSENGERS Kg	(Lbs)	100 PASSENGERS Kg	(Lbs)
APU	139.7	308						
Instruments	146.5	323						
Electronics	127.0	280	544.2	1200*	544.2	1200*	544.2	1200*
Electrical	322.9	712						
Installation for Above	597.3	1317	440.8	972	440.8	972	440.8	972
Electrical Generation	167.3	369	167.3	369	167.3	369	167.3	369
Hydraulics & Pneumatics	391.8	864	176.9	390	251.7	555	308.4	680
Flight Deck Accommodations	266.2	587	257.6	568	257.6	568	257.6	568
Passneger Accommodations	2829.5	6239	1391.4	3068	2151.9	4745	2737.9	6037
Cargo Accommodations	278.0	613	72.6	160	108.8	240	145.1	320
Emergency Accommodations	164.6	363	104.3	230	120.2	265	132.4	292
Air Conditioning	539.7	1190	306.1	675	458.1	1010	612.2	1350
Anti-Icing	96.1	212	142.9	315	206.3	455	254.0	560
TOTAL FIXED EQUIPMENT	6066.6	13,377)	3604.1	7,947	4706.9	10,379	5599.9	12,348

*Quoted From Study Guideline

TABLE 3.15 . FIXED EQUIPMENT - TILT ROTOR

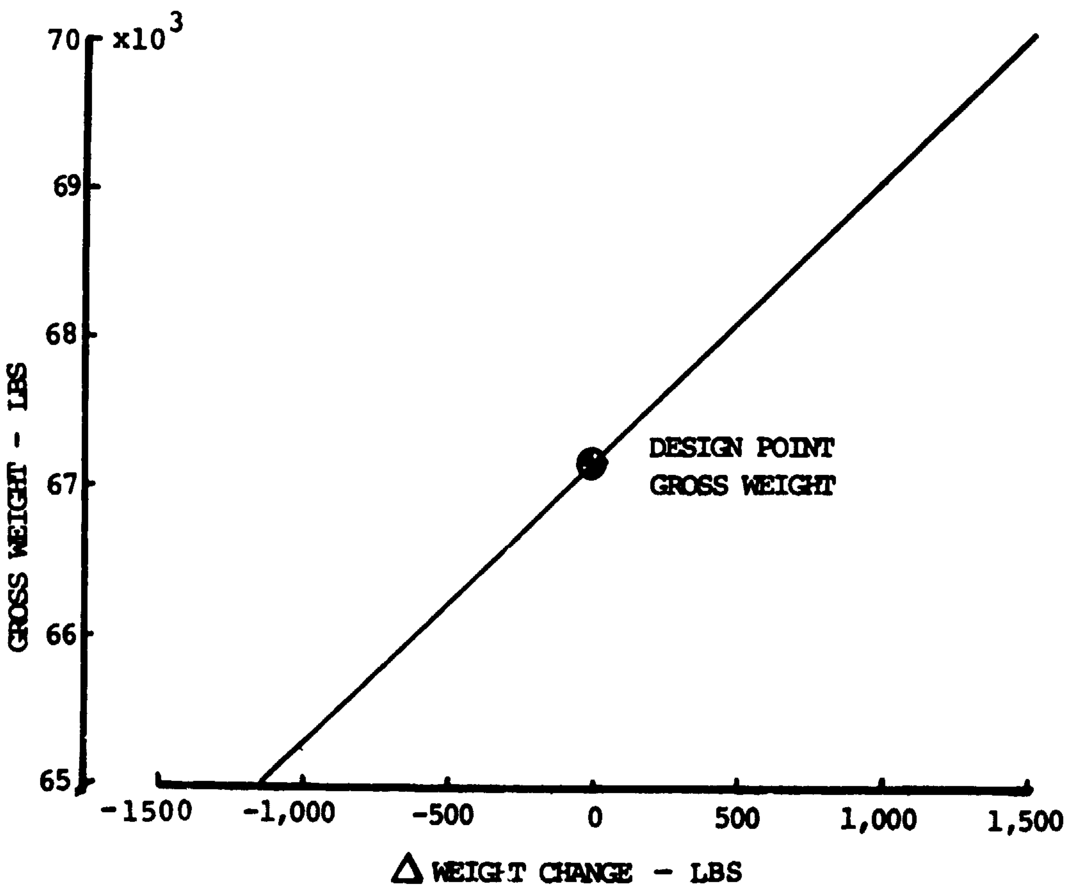


FIGURE 3.29. WEIGHT GROWTH AT CONSTANT PERFORMANCE AND STRENGTH - HELICOPTER.

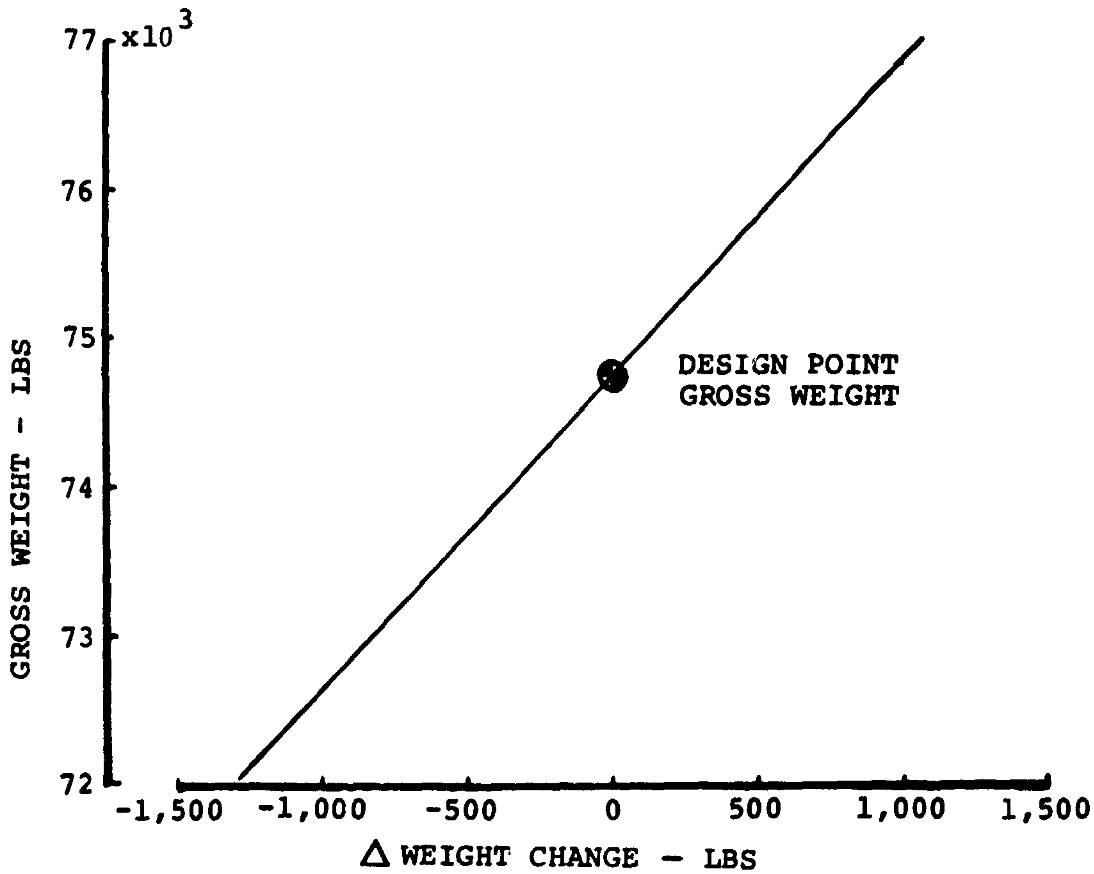


FIGURE 3.30. WEIGHT GROWTH AT CONSTANT PERFORMANCE AND STRENGTH - TILT ROTOR.

	737-200 89 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Seats and Belts	(58.5)	129	(49.9)	(110)	(49.9)	(110)	(49.9)	(110)
Pilot-CoPilot 40* X 2			36.3	80	36.3	80	36.3	80
Observer 30 X 1			13.6	30	13.6	30	13.6	30
Instrument Boards	47.6	105	47.6	105	47.6	105	47.6	105
Control Stands	31.7	70	31.7	70	31.7	70	31.7	70
Sound-Proofing	44.4	98	44.4	98	44.4	98	44.4	98
Lining	28.1	62	28.1	62	28.1	62	28.1	62
Manuals	2.3	5	2.3	5	2.3	5	2.3	5
Windshield Wiper	4.1	9	4.1	9	4.1	9	4.1	9
Rain Repellent System	10.0	22	10.0	22	10.0	22	10.0	22
Misc. Equipment	(10.6)	(23)	(10.6)	(23)	(10.6)	(23)	(10.6)	(23)
Sun Visor	2.3	5	2.3	5	2.3	5	2.3	5
Mirror	.5	1	.5	1	.5	1	.5	1
Foot Rests	.9	2	.9	2	.9	2	.9	2
Waste Containers	1.4	3	1.4	3	1.4	3	1.4	3
Ash Trays & Cup Holders	1.4	3	1.4	3	1.4	3	1.4	3
Stowage & Holders	3.2	7	3.2	7	3.2	7	3.2	7
Overhead Drain Tube	.9	2	.9	2	.9	2	.9	2
Lighting	15.4	34	15.4	34	15.4	34	15.4	34
Wiring, Etc.	13.6	30	13.6	30	13.6	30	13.6	30
TOTAL FLIGHT DECK ACCOMMODATIONS	266.3	587	257.7	568	257.7	568	257.7	568

*Quote From Study Outline

TABLE 3.16 . FLIGHT DECK ACCOMMODATIONS.

	737-200 88 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Seats and Belts	(1036.3)	(2285)	(377.3)	(832)	(558.7)	(1232)	(740.1)	(1632)
Passengers 16# Each*	1010.0	2227	362.8	800*	544.2	1200*	725.6	1600*
Attendants 16# Each*	26.3	58	14.5	32*	14.5	32*	14.5	32*
Lavatories 300# Each*	205.4	453	136.1	300*	272.1	600*	272.1	600*
Stowage	(206.8)	(456)	(117.0)	(258)	(176.4)	(389)	(233.5)	(515)
Overhead	138.3	305	79.4	175	119.3	263	158.7	350
Magazine	3.6	8	1.8	4	3.6	8	3.6	8
Coat Racks	33.6	74	18.1	40	27.2	60	36.3	80
Food Trays	4.5	10	2.3	5	3.6	8	4.5	10
Under Seat	26.8	59	15.4	34	22.7	50	30.4	67
Soundproofing	311.1	686	176.9	390	265.3	585	353.7	780
Lining	448.5	989	255.3	563	382.8	844	510.2	1125
Floor Covering	134.2	296	77.1	170	115.6	255	154.2	340
Beverage Service	192.3	424	108.8	240	163.7	361	218.6	482
Attendants Panels	9.5	21	6.8	15	9.1	20	9.1	20
Partitions	40.4	89	20.4	45	40.8	90	40.8	90
Window Shades	24.9	55	13.6	30	20.4	45	27.2	60
Lowered Ceiling	59.0	130	—	—	—	—	—	—
Wash & Drinking Facilities	30.4	67	15.4	34	22.7	50	30.4	67
Signs and Markings	.9	2	.9	2	.9	2	.9	2
Lighting	110.2	243	72.6	160	104.3	230	127.0	280
Safety Straps	1.8	4	1.8	4	1.8	4	1.8	4
Finishing Panels	17.7	39	11.3	25	17.2	38	18.1	40
TOTAL PASSENGER ACCOMMODATIONS	2829.4	6,239	1391.3	3,068	2151.8	4,745	2737.7	6,037

*Quote From Study Outline

TABLE 3.17. PASSENGER ACCOMMODATIONS.

	737-200 88 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Baggage Compartments	—	—	18.1	40	27.2	60	36.3	80
Insulation	60.8	134	18.1	40	27.2	60	36.3	80
Lining	112.0	247	36.3	80	54.4	120	72.6	160
Tie-Down	8.6	19	—	—	—	—	—	—
Nets	21.3	47	—	—	—	—	—	—
Partitions	33.1	73	—	—	—	—	—	—
Warm Air Ducts	7.7	17	—	—	—	—	—	—
Attachments	34.5	76	—	—	—	—	—	—
TOTAL CARGO ACCOMMODATIONS	278.0	613	72.5	160	108.8	240	145.2	320

TABLE 3.18. CARGO ACCOMMODATIONS.

	737-200 88 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Oxygen System	59.9	(132)	—	—	—	—	—	—
Passengers	43.1	95	—	—	—	—	—	—
Crew	16.8	37	—	—	—	—	—	—
Fire & Smoke Protectior	(52.2)	(115)	(39.4)	(87)	(44.0)	(97)	(47.2)	(104)
Detection	26.3	58	19.0	42	22.7	50	26.3	58
Extinguishing	20.9	46	20.4	45	21.3	47	20.9	46
Viewers - Cargo Comp. & Gear Downlock	5.0	(11)	—	—	—	—	—	—
Escape Provisions	(34.0)	(75)	—	—	—	—	—	—
Slides	29.5	65	—	—	—	—	—	—
Ropes	4.5	10	—	—	—	—	—	—
Hand Fire Extinguishers	14.1	31	14.1	31	14.1	31	14.1	31
First Aid	2.7	6	2.7	6	2.7	6	2.7	6
Axes	1.8	4	1.8	4	1.8	4	1.8	4
TOTAL EMERGENCY EQUIPMENT	164.7	363	58.0	128	62.6	138	65.8	145

TABLE 3.19. EMERGENCY EQUIPMENT - HEI OPTER.

	737-200 88 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Oxygen System	(59.9)	(132)	(46.3)	(102)	(57.6)	(127)	(66.7)	(147)
Passengers	43.1	95	29.5	65	40.8	90	49.9	110
Crew	16.8	37	16.8	37	16.8	37	16.8	
Fire & Smoke Protection	(52.2)	(115)	(39.4)	(87)	(44.0)	(97)	(47.2)	(104)
Detection	26.3	58	19.0	42	22.7	50	26.3	58
Extinguishing	20.9	46	20.4	45	21.3	47	20.9	46
Viewers - Cargo Comp. & Gear Downlock	5.0	(11)	—	—	—	—	—	—
Escape Provisions	(34.0)	(75)	—	—	—	—	—	—
Slides	29.5	65	—	—	—	—	—	—
Ropes	4.5	10	—	—	—	—	—	—
Hand Fire Extinguishers	14.1	31	14.1	31	14.1	31	14.1	31
First Aid	2.7	5	2.7	6	2.7	6	2.7	6
Axes	1.8	4	1.8	4	1.8	4	1.8	4
TOTAL EMERGENCY EQUIPMENT	164.7	363	104.3	230	120.2	265	132.5	292

TABLE 3.20. EMERGENCY EQUIPMENT - TILT ROTOR.

	737-200 88 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Flight Crew	154.2	340	172.3	380*	172.3	380*	172.3	380*
Flight Attendants	176.9	390	63.5	140*	127.0	280*	127.0	280*
Crew Baggage	56.7	125	42.6	94	56.7	125	56.7	125
Brief Cases & Navigational Equipment	11.3	25	11.3	25	11.3	25	11.3	25
Unusable Fuel	52.2	115	31.7	70	40.8	90	52.2	115
Oil	59.9	132	43.1	95	51.7	114	59.9	132
Emergency Equipment	(84.9)	(187)	(7.3)	(16)	(7.3)	(16)	(7.3)	(16)
Oxygen	16.3	36	—	—	—	—	—	—
Escape Slides	59.9	132	—	—	—	—	—	—
Fire Axe	1.4	3	—	—	—	—	—	—
Oranasal Masks	2.3	5	2.3	5	2.3	5	2.3	5
Smoke Goggles	.5	1	.5	1	.5	1	.5	1
Hand Megaphones	4.5	10	4.5	10	4.5	10	4.5	10
Passenger Accommodations	(664.0)	(1464)	(253.1)	(558)	(340.2)	(750)	(415.4)	(916)
Water	81.2	179	45.4	100	68.0	150	90.7	200
Toilet Chemicals	22.7	50	11.3	25	22.7	50	22.7	50
Beverage	77.6	171	90.7	200*	90.7	200*	90.7	200*
Serving Trays	5.4	12	3.2	7	5.0	11	6.3	14
Galley Structure	272.1	600	—	—	—	—	—	—
Galley Service Equipment	103.4	228	51.7	114	77.6	171	103.4	228
Passenger Service Equipt.	101.6	224	50.8	112	76.2	168	101.6	224
Passengers	7183.7	15,840	4081.6	9,000*	6122.4	13,500*	8163.3	18,000*
TOTAL USEFUL LOAD (NOT INCLUDING FUEL)	8443.8	18,618	4706.5	10,378	6929.7	15,280	9065.4	19,989

*Quoted From Study Outline

TABLE 3.21. USEFUL LOAD - HELICOPTER.

	737-200 88 PASSENGERS		50 PASSENGERS		75 PASSENGERS		100 PASSENGERS	
	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)	Kg	(Lbs)
Flight Crew	154.2	340	172.3	380*	172.3	380*	172.3	380*
Flight Attendants	176.9	390	63.5	140*	127.0	280*	127.0	280*
Crew Baggage	56.7	125	42.6	94	56.7	125	56.7	125
Brief Cases & Navigational Equipment	11.3	25	11.3	25	11.3	25	11.3	25
Unusable Fuel	52.2	115	31.7	70	40.8	90	52.2	115
Oil	59.9	132	43.1	95	51.7	114	59.9	132
Emergency Equipment	(84.9)	(187)	(17.3)	(38)	(20.9)	(46)	(23.6)	(52)
Oxygen	16.3	36	10.0	22	13.6	30	16.3	36
Escape Slides	59.9	132	--	--	--	--	--	--
Fire Axe	1.4	3	--	--	--	--	--	--
Oranasal Masks	2.3	5	2.3	5	2.3	5	2.3	5
Smoke Goggles	.5	1	.5	1	.5	1	.5	1
Hand Megaphones	4.5	10	4.5	10	4.5	10	4.5	10
Passenger Accommodations	(664.0)	(1464)	(253.1)	(558)	(340.2)	(750)	(415.4)	(916)
Water	81.2	179	45.4	100	68.0	150	90.7	200
Toilet Chemicals	22.7	50	11.3	25	22.7	50	22.7	50
Beverage	77.6	171	90.7	200*	90.7	200*	90.7	200*
Serving Trays	5.4	12	3.2	7	5.0	11	6.3	14
Galley Structure	272.1	600	--	--	--	--	--	--
Galley Service Equipment	103.4	228	51.7	114	77.6	171	103.4	228
Passenger Service Equipment	101.6	224	50.8	112	76.2	168	101.6	224
Passengers	7183.7	15,840	4081.6	9,000*	6122.4	13,500*	8163.3	18,000*
TOTAL USEFUL LOAD (NOT INCLUDING FUEL)	8443.8	18,618	47[illegible]5	10,400	6943.3	15,310	9081.7	20,025

*Quoted From Study Outline

TABLE 3.22 . USEFUL LOAD - TILT ROTOR.

BOEING VERTOL COMPANY

D210-10858-2

WEIGHT SUMMARY - PRELIMINARY DESIGN
(MIL-STD-1374)

	COMPUTER	TREND SUBSTAN-TIATION		
WING				
ROTOR	6678	6646		
TAIL				
SURFACES				
ROTOR				
BODY	6504	6472		
BASIC				
SECONDARY				
ALIGHTING GEAR GROUP	2687	2687		
ENGINE SECTION	491	489		
PROPULSION GROUP	9703	9668		
ENGINE INST'L	2200	2200		
EXHAUST SYSTEM *		44		
COOLING				
CONTROLS *		44		
STARTING *		73		
PROPELLER INST'L	*182			
LUBRICATING *		20		
FUEL	483	483		
DRIVE	6838	6804		
FLIGHT CONTROLS	2275	2263		
AUX. POWER PLANT	636	636		
INSTRUMENTS	423	423		
HYDR. & PNEUMATIC	680	680		
ELECTRICAL GROUP	834	834		
AVIONICS GROUP	648	648		
ARMAMENT GROUP				
FURN. & EQUIP. GROUP	7070	7070		
ACCOM. FOR PERSON.				
MISC. EQUIPMENT				
FURNISHINGS				
EMERG. EQUIPMENT				
AIR CONDITIONING	1150	1150		
ANTI-ICING GROUP	400	400		
LOAD AND HANDLING GP.				
WEIGHT EMPTY	40179	40066		
CREW				
TRAPPED LIQUIDS				
ENGINE OIL				
FUEL				
GROSS WEIGHT				

REV.

FORM 26391 (2/73)

DESIGN POINT TANDEM HELICOPTER - WEIGHT SUBSTANTIATION

ROTORS 6,646 LBS

BLADES (REF.-WEIGHT TREND CURVE, FIGURE 3.20)

$$W_B = 44\ K^{0.438}$$

$$K = \left(\frac{W_g}{10^4}\right)\left(LLF\right)\left(\frac{R^2}{100}\right)\left(\frac{R-r}{10}\right)\left(bCK_b\right)\left(\frac{R^{1.6}}{K_d t}\right)$$

$$\left(\frac{R^{1.6}}{K_d t}\right) = 1.0 \text{ OR GREATER}$$

WHERE:

W_B = Blade Weight Per Rotor

W_g = Design Gross Weight = 67,175 X .6 = 40,305 LBS

LLF = Limit Load Factor = 3.5

R = Rotor Radius = 34.45 FT

r = ℄ Rotation to Blade Attachment = 4.1 FT

b = Number of Blades Per Rotor = 4

C = Blade Chord = 2.68 FT

K_b = Rotor Type Factor - Articulated = 1.0

K_d = Droop Constant - Tandem = 1,000

t = Blade Thickness at 25% Chord = .32 FT

$$K = \left(\frac{40305}{10^4}\right)(3.5)\left[\frac{(34.45)^2}{100}\right]\left(\frac{34.45-4.1}{10}\right)\left[(4)(2.68)(1.0)\right]\left[\frac{(34.45)^{1.6}}{(1000)(.32)}\right]$$

$$= (4.03)(3.5)(11.87)(3.04)(10.72)(1.0)$$

$$= 5456$$

$$W_B = 44(5456)^{0.438} = 1{,}906 \text{ LBS PER ROTOR.}$$

<u>HUB</u> (REF.-WEIGHT TREND CURVE, FIGURE 3.2) 6,646 LBS

$$W_H = 61\ K^{0.358}$$

$$K = (W_b)(R)(N_R)^2 (P_R)(r)^{1.82}(b)^{2.5}(K_{amd})(10)^{-11}$$

WHERE:

W_H = Hub Weight Per Rotor

W_b = Blade Weight = 476.5 LBS EACH

R = Rotor Radius = 34.45 FT

N_R = Rotor RPM = 201

P_R = Rotor Horsepower Per Rotor =

13021 X 0.55 = 7161 HP

r = ℄ Rotation to Blade Attachment = 4.1 FT

b = Number of Blades Per Rotor = 4

K_{amd} = a x m x d = 1.0 X .54 X .62 = .33

$$K = (476.5)(34.45)(201)^2(7161)(4.1)^{1.82}(4)^{2.5}(.33)(10)^{-11}$$

$$=6539$$

$$W = 61(6539)^{0.358} = 1417 \text{ LBS PER ROTOR}$$

TOTAL ROTOR WEIGHT

BLADES = 1906
HUB = 1417
3323 X 2 = 6,646 LBS

<u>BODY</u> (REF. - WEIGHT TREND CURVE, FIGURE 3.24) 6,472 LBS

$$W_B = 120\ K^{0.8}$$

$$K = \left[\left(\frac{W_g}{10^4}\right)\left(N\right)\left(\frac{S_f}{10^3}\right)\left(L_C + L_{RW} + \Delta C.G.\right)\right]^{0.5}\left(\text{Log } V_{MAX}\right)$$

WHERE:

W_B = Body Weight

W_g = Design Gross Weight = 67,175 LBS

N = Ultimate Load Factor = 3.5 X 1.5 = 5.25

S_f = Wetted Area of Body Including Rotor Pylons = 3684.6 FT^2

L_C = Length of Cabin (Nose to End of Cabin Floor) = 67.3 FT

L_{RW} = Length of Rampwell = 0 FT

ΔCG = Center of Gravity Range = 2.8 FT

V_{MAX} = Maximum Speed = 225 KNOTS

$$K = \left[\left(\frac{67175}{10^4}\right)\left(5.25\right)\left(\frac{3684.6}{10^3}\right)\left(67.3 + 0 + 2.8\right)\right]^{0.5}\left(\text{Log } 225\right)$$

$$= 224.5$$

$$W_B = 125(224.5)^{0.8} = 9503$$

Reduction for Composite .361 (9503)	-3431
	6072
Add Air Stairs (1)	+400
TOTAL BODY WEIGHT	= 6472

ALIGHTING GEAR (4% GROSS WEIGHT) 2,687 LBS

$0.04(67175) = 2687$

ENGINE SECTION 489 LBS

Engine Mounts

$$W_{EM} = N_E(W_E \times N_{CLF})^{0.41}$$

WHERE:

W_{EM} = Weight of Engine Mount

N_E = Number of Engines = 2

W_E = Weight of Each Engine = 733 LBS

N_{CLF} = Nacelle Crash Load Factor = 24.1

$W_{EM} = 3(733 \times 24.1)^{0.41} = 165$ LBS

Nacelle

$$W_{NAC} = N_E(S_{NAC}) \text{ (PSF)}$$

WHERE:

W_{NAC} = Weight of Nacelle

N_E = Number of Engines = 2

S_{NAC} = Wetted Area = 143 Ft^2

PSF = Unit Weight = 1.5 LBS/FT^2

$W_{NAC} = 2(143)(1.5) = 429$ LBS

Reduction for Composite $(.361)(429) = -155$

274 LBS

Intake Duct - Center Engine

$$W_{ID} = S_D(PSF)$$

WHERE:

W_{ID} = Weight of Intake Duct

S_D = Duct Area = 52 FT^2

continued

$$PSF = \text{Unit Weight} = 1.5\ LBS/FT^2$$

W_{ID} = (52)(1.5) = 78

Reduction for Composite (.361)(78) = -28

50 LBS

TOTAL ENGINE SECTION

ENGINE MOUNTS	= 165
NACELLES	= 274
INTAKE DUCT (CENTER)	= 50

TOTAL ENGINE SECTION 489 LBS

ENGINES 2200 LBS

ENGINE INSTALLATION 181 LBS

EXHAUST (.02)(W_E)
(.02)(2200) = 44

LUBRICATION SYSTEM

(.009)(W_E)
(.009)(2200) = 20

CONTROLS (.02)(W_E)
(.02)(2200) = 44

STARTING (.033)(W_E)
(.033)(2200) = 73

FUEL SYSTEM 483 LBS

$W_{FS} = C\ W_F$

W_{FS} = Weight of Fuel System

$C = \dfrac{\text{Pounds of Fuel System}}{\text{Pounds of Fuel}} = .069$

W_F = Fuel Weight = 7007 LBS

W_{FS} = (.069)(7007) = 483

DRIVE SYSTEM (REF.-WEIGHT TREND CURVE, FIGURE 3.25) 6804 LBS

$$W_{DS} = 250\ (K_D)^{0.67}$$

$$K_D = \left(\frac{P_X}{N_R}\right)(Z)^{1/4}(K_T)$$

WHERE:

W_{DS} = Weight of Drive System

P_X = Drive System Power = 14,323 HP

N_R = Rotor RPM = 201

Z = Number of Stages in Main Drive System = 5

K_T = Configuration Factor, Tandem = 1.3

$$K_D = \left(\frac{14323}{201}\right)(5)^{1/4}(1.3)$$

$$= 138.52$$

$$W_{DS} = 250\ (138.52)^{0.67} = 6804$$

FLIGHT CONTROLS (FLY-BY-WIRE) 2263 LBS

COCKPIT CONTROLS

$$W_{CC} = 19.8 \left(\frac{W_g}{10^3}\right)^{0.41}$$

WHERE:

W_{CC} = Weight of Cockpit Controls

W_g = Design Gross Weight = 67,175 LBS

$$W_{CC} = 19.8 \left(\frac{67175}{10^3}\right)^{0.41} = 111$$

Reduction for Fly-By-Wire = .29 X 111 = -32

TOTAL COCKPIT CONTROLS = 79 LBS

ROTOR CONTROLS (POWER ACTUATORS THROUGH PITCH LINKS)

$$W_{RC} = 20 \left[C \sqrt{\frac{RW_B}{10^3}} \right]^{1.11} \times 2$$

WHERE:

W_{RC} = Weight of Rotor Controls

C = Blade Chord = 2.68 FT

R = Rotor Radius = 34.45 FT

W_B = Weight of Blades Per Rotor = 1906 LBS

$$W_{RC} = 20 \left[2.68 \sqrt{\frac{(34.45(1906)}{10^3}} \right]^{1.11} \times 2$$

= 1219 LBS

SYSTEM CONTROLS (FROM COCKPIT TO POWER ACTUATORS)

$$W_{SC} = 30 \left(\frac{W_R}{100} \right)^{0.84}$$

WHERE:

W_{SC} = Weight of System Controls

W_R = Weight of Rotors = 6646

$$W_{SC} = 30 \left(\frac{6646}{10^2} \right)^{0.84} = 1019$$

Reduction for Fly-
By-Wire = 0.2 X 1019 = -204
815 LBS

SAS 150 LBS

TOTAL FLIGHT CONTROLS

COCKPIT	=	79 LBS
ROTOR	=	1219 LBS
SYSTEM	=	815 LBS
SAS	=	150 LBS
		2263

FIXED EQUIPMENT (REF. TABLE 3.14) 11,841 LBS

BOEING VERTOL COMPANY

WEIGHT SUMMARY - PRELIMINARY DESIGN
(MIL-STD-1374)

	COMPUTER	TREND SUBSTAN-TIATION				
WING	4323	4310				
ROTOR	5246	5216				
TAIL	1404	1427				
SURFACES	1404	1427				
ROTOR						
BODY	8495	8509				
BASIC						
SECONDARY						
ALIGHTING GEAR GROUP	2990	2990				
ENGINE SECTION	948	948				
PROPULSION GROUP	10476	10475				
ENGINE INST'L	2611	2611				
EXHAUST SYSTEM *						
COOLING						
CONTROLS *						
STARTING *						
PROPELLER INST'L	* 810	*809				
LUBRICATING *						
FUEL	219	219				
DRIVE	6836	6836				
FLIGHT CONTROLS	4046	4053				
AUX. POWER PLANT	636	636				
INSTRUMENTS	423	423				
HYDR. & PNEUMATIC	680	680				
ELECTRICAL GROUP	834	834				
AVIONICS GROUP	648	648				
ARMAMENT GROUP						
FURN. & EQUIP. GROUP	7217	7217				
ACCOM. FOR PERSON.						
MISC. EQUIPMENT						
FURNISHINGS						
EMERG. EQUIPMENT						
AIR CONDITIONING	1350	1350				
ANTI-ICING GROUP	560	560				
LOAD AND HANDLING GP.						
WEIGHT EMPTY	50276	50276				
CREW						
TRAPPED LIQUIDS						
ENGINE OIL						
FUEL						
GROSS WEIGHT						

REV.

DESIGN POINT TILT ROTOR WEIGHT SUBSTANTIATION

WING (REF.-WEIGHT TREND CURVE, FIGURE 3.26) 4310 Lbs.

$$W = 291.6\ (K)^{0.585}$$

$$K = \left(\frac{R_M\ W_{XW}}{10^4}\right)\left(\frac{S_W}{10^2}\right)\left(\mathrm{Log}_{10}\ \frac{b}{B}\right)\left(\sqrt{\frac{1+\lambda}{2K_r}}\right)\left(\sqrt{\ \ N}\right)\left(\mathrm{Log}_{10}V_D\right)\left(\mathrm{Log}_{10}AR\right)$$

WHERE:

W_W = Weight of Wing

R_M = Relief Term - Assume Design Lift Is On Wing Tip (100% Span) = 0.6

W_{XW} = Gross Weight Less Items at Center of Lift = 55,390 Lbs.

GROSS WEIGHT	74,749
ROTORS	5,246
WING	4,323
ENGINE SECTION	948
PROPULSION	10,476
ROTOR CONTROLS	1,511
TILT MECHANISM	650
FUEL	4,448
TRAPPED LIQUIDS	115
OIL	132
TOTAL W_{XW}	46,900

S_W = Planform Wing Area = 747.5 Ft.^{2}

b = Wing Span, = 73.1 Ft.

B = Maximum Fuselage Width = 14.8 Ft.

λ = Wing Taper Ratio = 1.0

K_r = Wing Root Thickness, % Chord = .21

N = Ultimate Load Factor = 3.75

V_D = Dive Velocity = 360 Knots

AR = Aspect Ratio - 7.14

$$K = \left[\frac{(.6)(46,900)}{10^4}\right]\left(\frac{747.5}{10^2}\right)\left(\mathrm{Log}_{10}\frac{73.1}{14.8}\right)\left[\sqrt{\frac{1+1}{2(.21)}}\right]\left(\sqrt{3.75}\right)\left(\mathrm{Log}_{10}360\right)\left(\mathrm{Log}_{10}7.14\right)$$

$$= (2.81)(7.48)(.69)(2.18)(1.94)(2.56)(.85) = 133.4$$

$$W_W = 291.6\ (133.4)^{0.585} = 5105$$

Add: Wing-Pod Attachments

.036 (Pod Weight)

.036 (20,136)	=	+ 747
		5852
Reduce for Composites		
0.302(5105)	=	-1542
		4310

ROTORS (REF.-WEIGHT TREND CURVE, FIGURE 3.22) 5216 Lbs.

$$W_R = 15.0\ K^{0.67}$$

$$K = (r)^{0.2}\left(\frac{HP_R}{100}\right)^{0.5}\left(\frac{V_{tL}}{100}\right)\left(\frac{R.b.C}{10}\right)\left(\frac{R^{1.6}}{K_d t}\right)$$

$$\left(\frac{R^{1.6}}{K_d t}\right) = 1.0 \text{ OR GREATER}$$

WHERE:

W_R = Weight Of One Rotor

r = Center Line of Rotation To Blade Attachment Point = 2.11 Ft.

HP_r = Horsepower (Xmsn Limit Per Rotor) = 16,579 x .55 = 9,118

continued

V_{TL} = Design Limit Tip Speed = 775 X 1.1 = 852.5 FT/SEC

R = Rotor Radius = 28.15 FT

b = Number of Blades Per Rotor = 3

C = Blade Chord = 2.65 FT

K_d = Droop Constant = 1000

t = Blade Thickness = .12(2.65) = .318

$$K = (2.11)^{0.25}\left(\frac{9118}{100}\right)^{0.5}\left(\frac{852.5}{100}\right)\left(\frac{28.15 \text{ X } 3 \text{ X } 2.65}{10}\right)\left[\frac{(28.15)^{1.6}}{(1000)(.318)}\right]$$

$$= (1.21)(9.55)(8.53)(22.38)(1.0)$$

$$= 2206$$

$$W_R = 15.0(2206)^{0.67} = 2608 \text{ X } 2 = 5216$$

HORIZONTAL TAIL (REF.-WEIGHT TREND CURVE, FIGURE 3.27) 754 LBS

$$W_{HT} = 350(K)^{0.54}$$

$$K = (F_H)\left(\frac{S_H}{10^2}\right)\left(\frac{\text{Log } V_D}{T_{MA} X t}\right)$$

$$F_H = \left(\frac{W_g}{10^4}\right)\left(\frac{K_y}{10}\right)\left(\frac{b_H}{10}\right)\left(\frac{1 + 2\lambda}{1 + \lambda}\right)(K_{TL})$$

WHERE:

W_{HT} = Weight of Horizontal Tail

S_H = Tail Plan Area = 261.7 FT^2

V_D = Dive Velocity = 350 KNOTS

T_{MA} = Tail Moment Arm = 46.8 FT

continued

t = Root Thickness = 1.02 FT

W_g = Design Gross Weight = 74, 149 LBS

K_y = Pitch Radius of Gyration = 16.65 FT (Figure 3.31)

b_H = Tail Span = 35.0 FT

λ = Taper Ratio = .471

K_{TL} = Tail Load Factor = 1.0

$$F_H = \left(\frac{74,749}{10^4}\right)\left(\frac{16.65}{10}\right)\left(\frac{35.0}{10}\right)\left(\frac{1+.942}{1+.471}\right)(1.0)$$

$$= 57.6$$

$$K = (57.6)\left(\frac{261.7}{10^2}\right)\left(\frac{\text{Log}_{10}\ 360}{46.8 \times 1.02}\right)$$

$$= 8.07$$

$$W_{HT} = 350\ (8.07)^{.54} = 1080$$

Reduction for Composite .302 X 1080 = <u>-326</u>

HORIZONTAL TAIL WEIGHT = 754

<u>VERTICAL TAIL</u> (REF.-WEIGHT TREND CURVE, FIGURE 3.28) 673 LBS

$$W_{VT} = 360\ (K)^{0.54}$$

$$K = \left[(FV) + \left(\frac{aF_H}{2b_V}\right)\right]\left(\frac{S_V}{10^2}\right)\left(\frac{\text{Log}_{10}V_D}{T_{MA} X t}\right)$$

$$F_V = \left(\frac{W_g}{10^4}\right)\left(\frac{K_Z}{10}\right)\left(\frac{b_V}{10}\right)\left(\frac{1+2\lambda}{1+\lambda}\right)$$

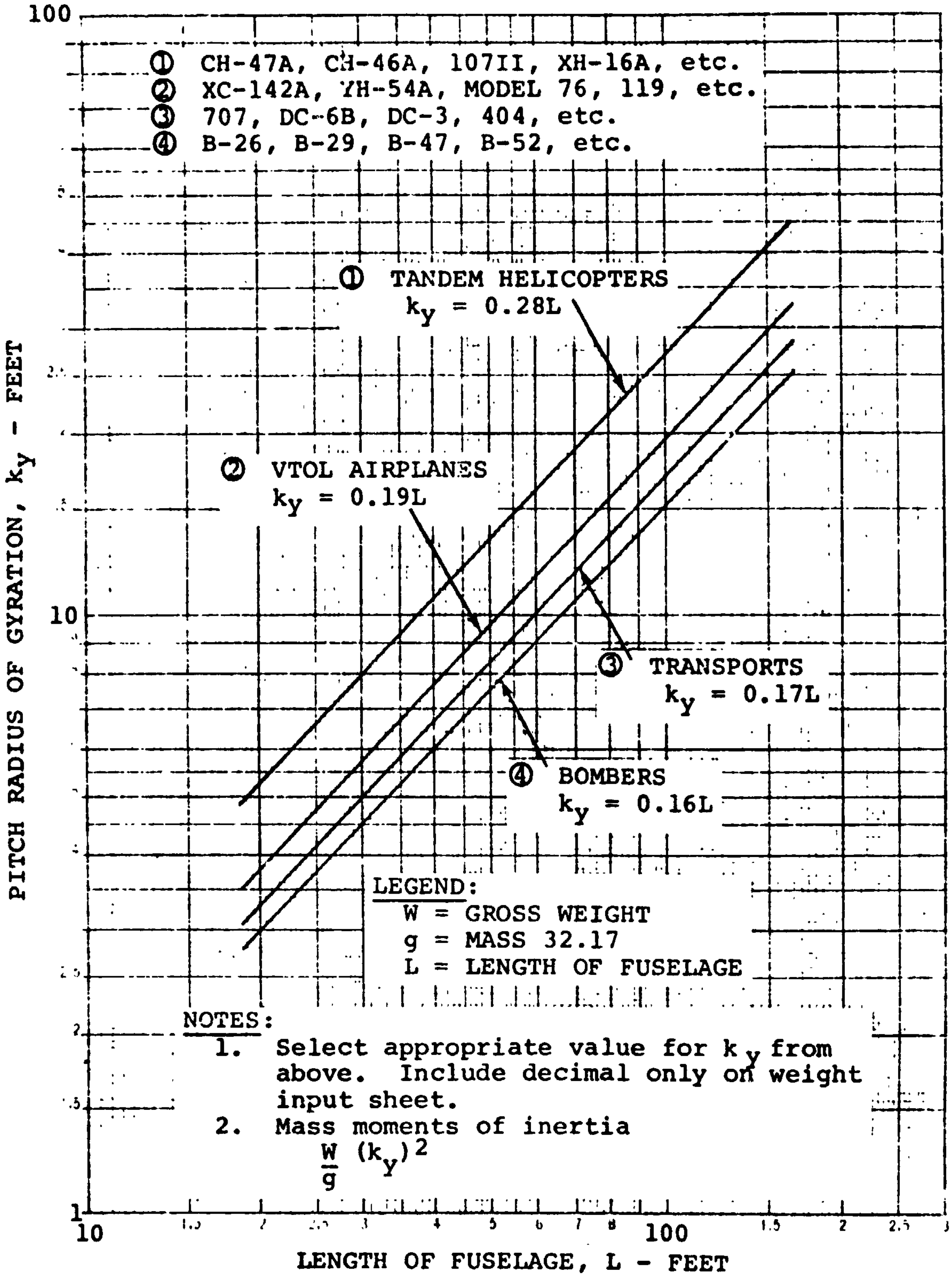


FIGURE 3.31. RADIUS OF GYRATION TREND - PITCH.

continued

WHERE:

W_{VT} = Weight of Vertical Tail

a = Height of Horizontal Tail Above Root Chord = 17.6 FT

b_V = Tail Span = 17.6 FT

S_V = Tail Area =221.9 FT^2

V_D = Dive Velocity = 360 KNOTS

T_{MA} = Tail Moment Arm = 38.6 FT

t = Root Thickness = 1.74 FT

W_g = Design Gross Weight = 74,149 LBS

K_Z = Yaw Radius of Gyration = 25.9 FT (Figure 3.32)

λ = Taper Ratio = 0.447

$$F_V = \left(\frac{74,749}{10^4}\right)\left(\frac{25.9}{10}\right)\left(\frac{17.6}{10}\right)\left(\frac{1 + 2 \text{ X } .447}{1 + .447}\right)$$

$$= 44.6$$

$$K = \left[(44.6) + \left(\frac{17.6 \text{ X } 57.6}{2 \text{ X } 17.6}\right)\right]\left(\frac{221.9}{10^2}\right)\left(\frac{\text{Log}_{10} 360}{38.6 \text{ X } 1.74}\right)$$

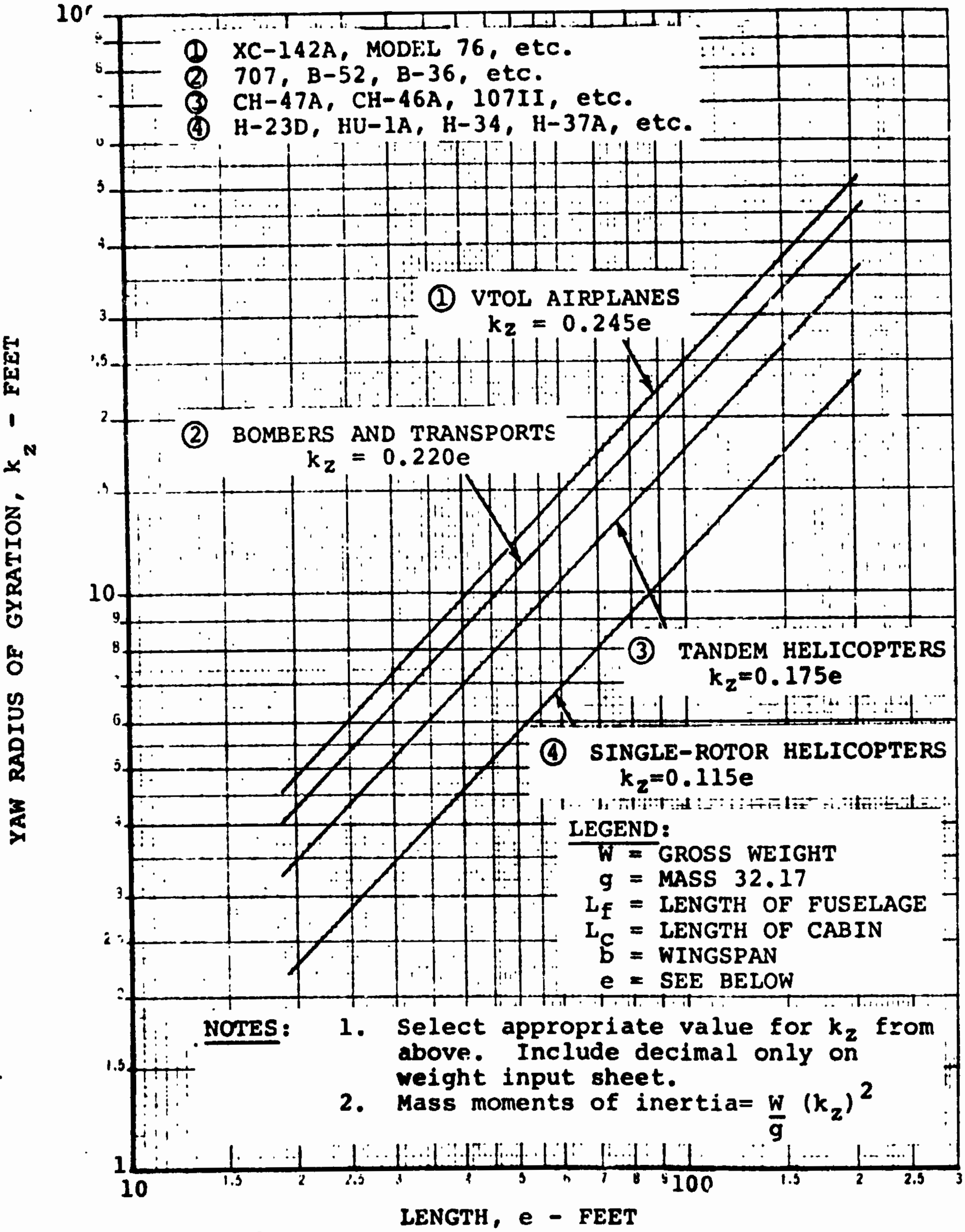
$$= (73.4)(2.22)(.038)$$

$$= 6.2$$

$$W_{VT} = 360(6.2)^{0.54} = 964$$

Reduction for Composite .302 X 964 $= \underline{-291}$

VERTICAL TAIL WEIGHT= 673



$$e = \frac{b + L_f}{2} \text{ (AIRPLANES)} \qquad e = L_f+L_c \text{ (HELICOPTERS)}$$

FIGURE 3.32. RADIUS OF GYRATION TREND - YAW.

BODY (REF.-WEIGHT TREND CURVE, FIGURE 3.23) 8509 LBS

$$W_B = 126.0\ (K)^{0.508}$$

$$K = \left(\frac{W_X}{10^4}\right)^{0.7}\left(\frac{S_f}{10^3}\right)(B)(L_f + L_{RW})^{0.5}(\mathrm{Log}_{10}V_D)(\Delta_p+1)^{0.2}(N)^{0.3}$$

WHERE:

W_B = Weight of Body

W_{XB} = Weight of Fuselage and Contents = 46,900 LBS

GROSS WEIGHT = 74,749 LBS

LESS

ROTORS	-5,246
WING	-4,328
ENGINE SECTION	- 948
PROPULSION	-10,476
ROROR CONTROLS	-1,511
TILT MECHANISM	- 650
FUEL	-4,448
TRAPPED LIQUIDS	- 115
OIL	- 132

TOTAL W =46,900 LBS

S_f = Wetted Area = 346.4 FT^2

B = Body Width = 14.8 FT

L_f = Length of Fuselage = 92.5 FT

L_{RW} = Length of Ramp Well = 0 FT

V_D = Dive Velocity = 360 KNOTS

Δ_p = Limit Differential Cabin Pressure = 3.13 PSI

N = Ultimate Load Factor = 3.75

continued

$$K = \frac{\left(\frac{46,900}{10^4}\right)^{0.7}\left(\frac{346.4}{10^3}\right)^{0.5}(14.8)(92.5+0)^{0.5}(\text{Log}_{10}360)}{(3.13+1)^{0.2}(3.75)^{0.3}}$$

$$= (2.95)(3.46)(14.8)(9.62)(2.56)(1.33)(1.49)$$

$$= 7372.5$$

$W_B = 126(7372.5)^{0.508} = 11,618$

Reduce for Composite .302 X 11618	= -3,509
	8,109
Add Air Stairs (1)	+400
	8,509

<u>LANDING GEAR (4% DESIGN GROSS WEIGHT)</u> 2,990 LBS

0.04(74,749) = 2,990

<u>ENGINE SECTION (52% ENGINE WEIGHT)</u> 948 LBS

0.52(2611)	= 1,358
Reduce for Composite .302(1358)	= -410
ENGINE SECTION WEIGHT	= 948 LBS

<u>ENGINES</u> 2,611 LBS

<u>ENGINE INSTALLATION (31% ENGINE WEIGHT)</u> 809 LBS

(0.31)(2611) = 809

<u>FUEL SYSTEM (4.9% FUEL)</u> 219 LBS

(0.049)(4448) = 219

DRIVE SYSTEM (REF.-WEIGHT TREND CURVE, FIGURE 3.25) 6,836 LBS

$$W_{DS} = 265.5 \ (K)^{0.67}$$

$$K = \left(\frac{HPX1.1}{RPM} \right) (Z)^{0.25} (K_T)$$

WHERE:

W_{DS} = Weight of Drive System

HP = Total Horsepower = 16,579

RPM = Rotor Design RPM = 262.9

Z = Number of Stages in Main Drive = 4

K_T = Configuration Factor = 1.3

$$K = \left(\frac{16579 \ X \ 1.1}{262.9} \right) (4)^{0.25} (1.3) = 127.53$$

$$W_{DS} = 265.5 (127.53)^{0.67} = 6,836$$

FLIGHT CONTROLS (FLY-BY-WIRE) 4,053 LBS

Cockpit

$$W_{CC} = 26 \left(\frac{W_g}{10^4} \right)^{0.41}$$

WHERE:

W_{CC} = Weight of Cockpit Controls

W_g = Design Gross Weight = 74,749 LBS

$$W_{CC} = 26 \left(\frac{74749}{10^3} \right)^{0.41} = 152$$

Reduce for Fly-By-
Wire 0.29(152) = -44

TOTAL COCKPIT CONTROLS= 108

continued

Rotor Controls

$$W_{RC} = 0.30 \ (W_R)$$

WHERE:

W_{RC} = Weight of Rotor Controls

W_R = Weight of Rotor = 5,246 LBS

$$W_{RC} = 0.30(5246)$$

$$= 1574$$

System Controls

$$W_{SC} = 45 \left(\frac{W_R}{100}\right)^{0.84}$$

WHERE:

W_{SC} = Weight of System Controls

W_R = Weight of Rotor = 5,246 LBS

$$W_{SC} = 41 \left(\frac{5246}{100}\right)^{0.84} = 1141$$

Reduce for Fly-By-
Wire 0.20 X 114.1 = -228

TOTAL SYSTEM CONTROLS= 913

Airplane Controls

$$W_{AC} = 0.011 \ (W_g)$$

WHERE:

W_{AC} = Weight of Airplane Control System

W_g = Design Gross Weight = 74,749 LBS

continued

$W_{AC} = 0.011(74,749) = 822$

Reduce for Fly-By-Wire 0.2(822) $= -164$

TOTAL AIRPLANE CONTROLS = 658

SAS - Estimated Weight = 150 LBS

Tilt Mechanism

$$W_{TM} = 0.010\ (W_g)$$

WHERE:

W_{TM} = Weight of POD Tilting Mechanism

W_g = Design Gross Weight = 74,749 LBS

$W_{TM} = 0.010(74,749) = 747$

Reduce for Fly-By-Wire 0.13(747) $= -97$

TOTAL TILT MECHANISM 650

SUMMARY OF FLIGHT CONTROLS WEIGHT

COCKPIT	=	108
ROTOR	=	1,574
SYSTEM	=	913
AIRPLANE	=	658
SAS	=	150
TILT MECH.	=	650
TOTAL		4,053

FIXED EQUIPMENT (Ref. - Table 3.15) 12,348 LBS

3.3 Noise

The prediction of aircraft exterior perceived noise levels was based on rotor noise prediction methodology which has been under development, at Boeing Vertol, over the past several years. The underlying approach is derived from that developed by Ollerhead and Lowson and reported in USAAMR-DL TR68-60. The procedure, which starts with airload distributions in the rotating system and calculates sound pressures at any point in the stationary system, is mathematically rigorous but is limited by the accuracy of the assumed airloads. Since many airload harmonics are required to calculate one sound harmonic, and since many sound harmonics are required to define an acoustical spectrum, definition of higher frequency airloads than are analytically derivable is required. As a result the basis for rotor noise input is experimental data.

Boeing Vertol has been expending considerable effort through Government and Company funded research programs in order to establish a reliable basis for calculating rotor noise. Two approaches have been taken, the first involves assuming airloads and calculating noise for comparison with sound pressure data, the second approach utilizes measured airloads and uses these as analytical input.

Work done with helicopter rotors using assumed airloads as input is illustrated in Figure 3.33 which compares predictions using the Lowson-Ollerhead Program (Heron II) with a revised program (ROTNO) which, among other changes revised the "harmonic loading law" and resulted in better correlation with test data.

Since tilt rotors employ greater blade twist which moves the peak pressures further inboard, and since the tilting rotor has greater variability in inflow direction, further modifications to the program are required. An initial study entitled "Optimal Noise Reduction Trajectories for Tilt Rotor Aircraft" (NAS2-5025) considered loading law variations due to nacelle position, and proximity between rotor blades and tip vortices shed by other blades in the system.

Correlation of measured pressures and acoustical data on an 8-foot diameter model blade, performed under Contract NAS 2-5473, is shown in Figure 3.34. This work was used to refine sound pressure predictions for tilt rotor aircraft.

With respect to broadband (sometimes called Vortex) noise the state-of-the-art of prediction is even less established. To date no fundamental derivation based on a verified

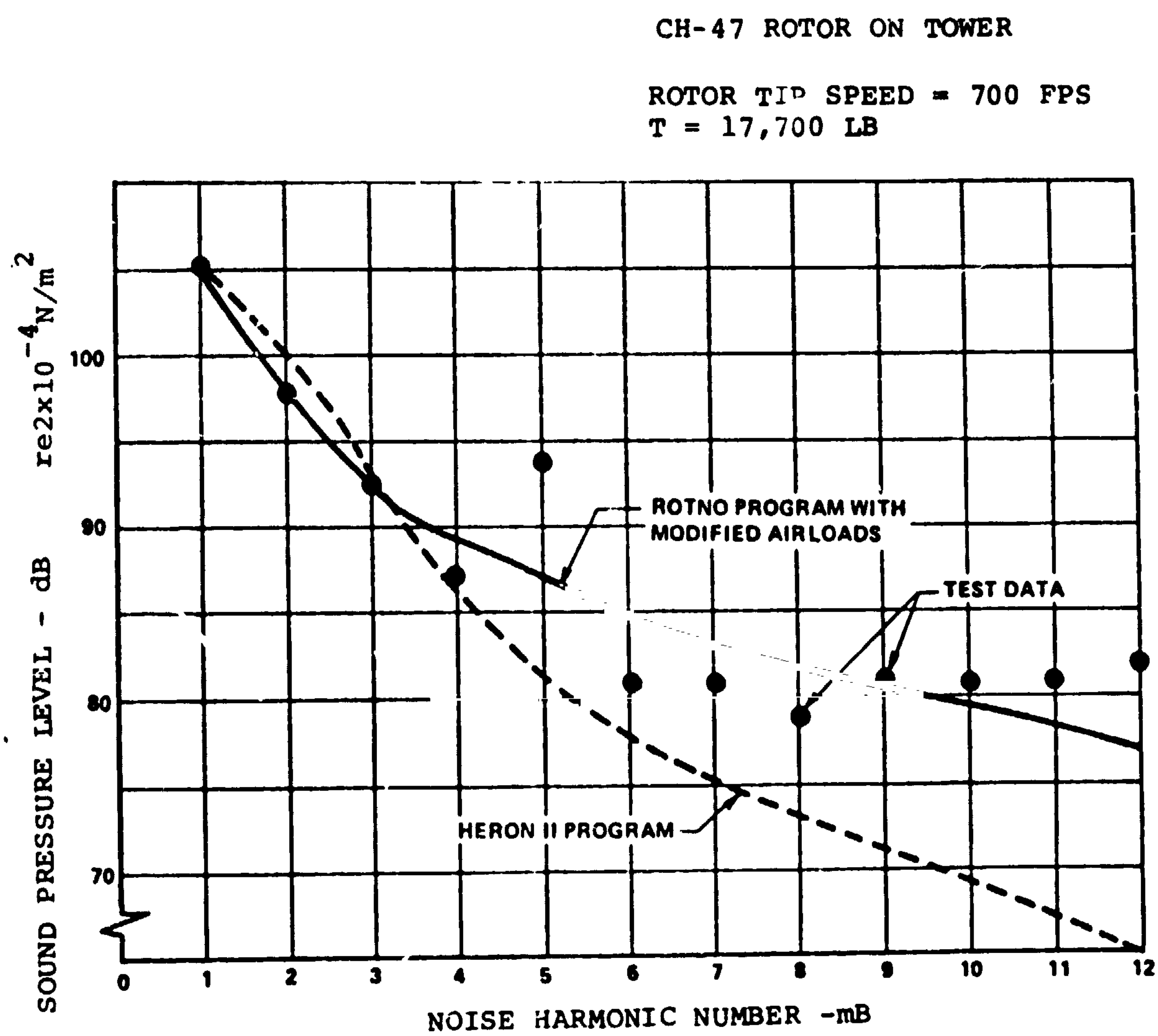


FIGURE 3.33. COMPARISON OF ROTATIONAL NOISE PREDICTION METHODS.

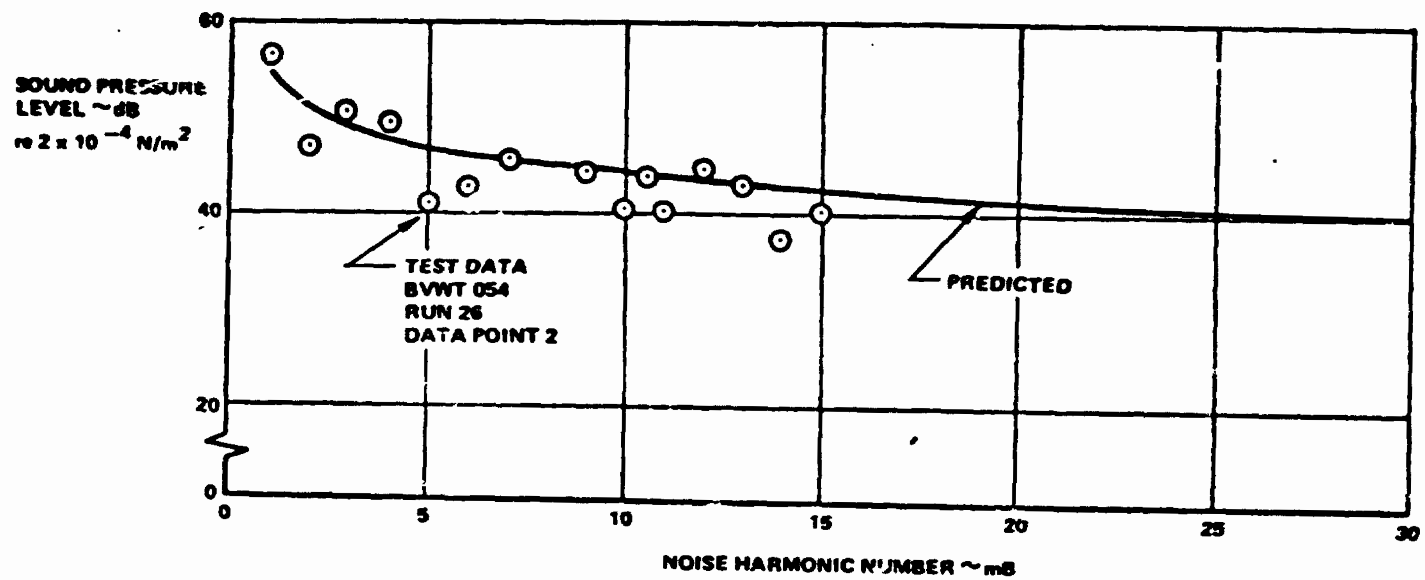


FIGURE 3.34 . CORRELATION OF THEORETICAL AND MEASURED ACOUSTIC DATA FROM MEASURED AIRLOADS.

method of noise generation has been developed although several empirical formulas exist in the literature. Of these, Boeing Vertol has found that the method of Schlegel, King and Mull (U.S. AAVLABS Report TR 66-4) appears to follow trends as well as any available procedure, but is generally low with respect to absolute value. Therefore the broadband noise prediction is based on the above method with 5 db added at all frequencies. This assumption is the same as that arrived at independently by Ollerhead and Lowson and discussed in their report TR 68-60 previously mentioned.

Boeing Vertol also has an operational computer program which uses flight trajectory and operating parameters (e.g. thrust, tip speed, etc.) to predict 1/3 octave spectra at specified ground locations. This method was used to predict the perceived noise level time histories given in Volume 1.

3.4 FLYING QUALITIES

3.4.1 Tandem Rotor Helicopter Flying Qualities

The stability and control data for the tandem helicopter was evaluated using trim and stability computer programs developed and validated at Boeing Vertol. The fuselage and pylon contribution to the derivatives are obtained from wind tunnel data for similar configurations. The computer program used to obtain the overall aircraft derivatives is A-97 which determines both trim conditions and the stability derivatives. Derivatives for hover and cruise at extreme c.g. conditions for a range of gross weights are presented in Tables 3.25a through 3.25j. The non-dimensional form of the derivative is discussed below. The sign convention conforms to the stability axes rotation.

To evaluate gust response a CSMP program was written for gust analysis and the aircraft response on a range of (1-cosine) gusts of varying length was determined.

Derivative Units

The X, Y, and Z force derivatives have been non-dimensionalized by mass, and the L, M and N moment derivatives have been non-dimensionalized by inertia. The derivatives are therefore expressed in terms of linear (ft/sec^2) and angular (rad/sec^2) accelerations per unit perturbation.

The unit perturbations are expressed in the following units

u, v, w	linear velocities	ft/sec
p, q, r	angular velocities	rad/sec
δ_B, δ_S, δ_R, δ_C	control inputs	in.
β, α	angles	rad

PROG A9740 JOB 5761

```
STABILITY DERIVATIVES OUTPUT

      MASS             IXX              IYY              IZZ
  1.336483D 03    7.200000D 04    1.061000D 06    1.021000D 06

      XU               XP               XDELB            XDELTAC
      XV               XQ               XDELS            XBETA
      XW               XR               XDELR            XALPHA
 -1.193799D-02    6.294131D-01    2.254915D-01    4.795102D-01
  3.476870D-03    4.165050D-02   -1.361848D-02    1.106722D-02
  1.159597D-02   -1.545294D-01   -8.560445D-02    3.691111D-02

      ZU               ZP               ZDELB            ZDELTAC
      ZV               ZQ               ZDELS            ZBETA
      ZW               ZR               ZDELR            ZALPHA
  1.185986D-02   -2.121536D-01    5.306103D-02   -1.069029D 01
  1.221519D-03   -2.416173D 00   -2.532575D-03    3.888215D-03
 -3.243043D-01   -1.534334D-01   -1.057470D-02   -1.032293D 00

      MU               MP               MDELB            MDELTAC
      MV               MQ               MDELS            MBETA
      MW               MR               MDELR            MALPHA
  2.499484D-03   -1.677909D-02    1.987295D-01   -8.429846D-02
  3.573824D-05   -7.473172D-01    2.473956D-04    1.137584D-04
 -3.062589D-03   -1.681515D-01    4.170492D-03   -9.748524D-03

      YU               YP               YDELB            YDELTAC
      YV               YQ               YDELS            YBETA
      YW               YR               YDELR            YALPHA
 -3.996827D-03   -6.719663D-01   -2.738540D-02    4.672216D-02
 -3.231419D-01    7.281741D-01    1.129101D 00   -1.028592D 00
  1.255610D-03    9.215711D-03    6.158255D-02    3.996732D-03

      LU               LP               LDELB            LDELTAC
      LV               LQ               LDELS            LBETA
      LW               LR               LDELR            LALPHA
 -1.399215D-03   -7.444440D-01   -2.561498D-02    1.493794D-03
 -5.654500D-03    4.729000D-01    4.720716D-01   -1.799883D-02
  5.165666D-04    4.780903D-02   -2.523696D-01    1.644282D-03

      NU               NP               NDELB            NDELTAC
      NV               NQ               NDELS            NBETA
      NW               NR               NDELR            NALPHA
 -2.460297D-05   -7.516495D-03    1.783752D-02   -6.919952D-03
  1.630974D-03   -1.056946D-01    3.649387D-04    5.191552D-03
 -2.244484D-04   -4.069975D-02    1.246172D-01   -1.032751D-03
```

TABLE 3.25a. TANDEM HELICOPTER STABILITY DERIVATIVES:

Gross Weight	43,000 Lb
Airspeed	0 Kt
C.G.	Mid
Altitude	S.L., 90°F

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
1.787158D 03	9.500000D 04	1.161000D 06	1.121000D 06

XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-1.517706D-02	5.377153D-01	1.735602D-01	3.798940D-01
4.813515D-03	5.408401D-01	-2.183658D-02	1.532190D-02
8.667091D-03	-1.490610D-01	-1.165633D-01	2.758821D-02

ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
9.895842D-03	-1.817947D-01	3.963809D-02	-8.376567D 00
2.719352D-03	-2.449744D 00	-7.483089D-03	8.655965D-03
-2.560641D-01	-8.169136D-03	-2.961359D-02	-8.150773D-01

MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
2.572075D-03	-1.449937D-02	1.867673D-01	-1.164134D-01
1.768591D-04	-7.248827D-01	5.967891D-04	5.629601D-04
-4.092783D-03	-2.055532D-01	5.354389D-03	-1.302773D-02

YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-5.390634D-03	-9.867596D-01	-4.752954D-02	5.177547D-02
-3.193614D-01	7.082907D-01	1.128389D 00	-1.016559D 00
1.364252D-03	1.568584D-04	2.506354D-01	4.342550D-03

LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-1.581805D-03	-6.699675D-01	-2.868233D-02	8.391009D-03
-1.186537D-02	4.387588D-01	4.242276D-01	-3.776864D-02
8.119156D-04	6.569061D-02	-2.099173D-01	2.584408D-03

NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-8.608948D-05	-1.406266D-02	1.979505D-02	-9.667272D-03
3.110911D-03	-1.182781D-01	-1.689094D-04	9.902338D-03
-5.182316D-04	-5.646788D-02	1.497367D-01	-1.649582D-03

TABLE 3.25b TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	57,500 Lb
Airspeed	0 Kt
C.G.	Fwd
Altitude	S.L., 90°F

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
1.787158D 03	9.500000D 04	1.161000D 06	1.121000D 06

XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-1.509349D-02	7.353446D-01	1.707910D-01	3.692001D-01
4.304122D-03	5.133179D-01	-9.933565D-03	1.370045D-02
8.548049D-03	-1.471253D-01	-1.166866D-01	2.720928D-02
ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
7.952955D-03	-2.173105D-01	9.582708D-02	-8.440549D 00
4.790972D-04	-1.528354D 00	-2.623852D-03	1.525014D-03
-2.564788D-01	-1.771225D-01	-6.531694D-03	-8.163975D-01
MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
2.495710D-03	-2.298780D-02	1.876956D-01	-6.359021D-02
-1.715272D-04	-6.986795D-01	-5.910419D-06	-5.459880D-04
-2.207089D-03	-2.061526D-01	4.756265D-03	-7.025383D-03
YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-4.458337D-03	-9.960024D-01	-7.538891D-03	4.156982D-02
-3.199574D-01	7.722318D-01	1.131406D 00	-1.018456D 00
8.227012D-04	-1.505053D-02	-8.065296D-02	2.618739D-03
LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-1.520798D-03	-7.039227D-01	-2.066533D-02	-8.110838D-05
-1.226037D-02	4.598922D-01	4.371577D-01	-3.902597D-02
3.549378D-04	5.497905D-02	-2.792247D-01	1.129802D-03
NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-8.246249D-05	1.056338D-03	1.974930D-02	-7.048258D-03
1.003649D-03	-1.164345D-01	3.955523D-04	3.194713D-03
-2.810454D-04	-5.484741D-02	1.520396D-01	-8.945952D-04

TABLE 3.25c. TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	57,500 Lb
Airspeed	0 Kt
C.G.	Aft
Altitude	S.L., 90°F

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
2.087866D 03	1.050000D 05	1.201000D 06	1.161000D 06
XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-1.747506D-02	5.716403D-01	1.483260D-01	3.298828D-01
5.538211D-03	7.871022D-01	-2.265455D-02	1.762867D-02
7.157376D-03	-1.317143D-01	-1.368577D-01	2.278264D-02
ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
8.484942D-03	-1.383997D-01	6.079931D-02	-7.317965D 00
2.518616D-03	-2.090961D 00	-6.532756D-03	8.017004D-03
-2.243912D-01	-7.613905D-04	-2.796406D-02	-7.142593D-01
MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
2.637372D-03	-1.766305D-02	1.825882D-01	-1.157291D-01
1.312009D-04	-7.100992D-01	5.952876D-04	4.176253D-04
-4.002750D-03	-2.327972D-01	6.560416D-03	-1.274115D-02
YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-6.113184D-03	-1.164005D 00	-4.375345D-02	5.010478D-02
-3.182798D-01	7.272862D-01	1.127220D 00	-1.013116D 00
1.085019D-03	-1.287069D-02	2.308667D-01	3.453724D-03
LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-1.854109D-03	-6.948635D-01	-2.896814D-02	8.846500D-03
-1.599269D-02	4.527350D-01	4.293686D-01	-5.090631D-02
7.708172D-04	7.681109D-02	-2.216967D-01	2.453587D-03
NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-1.279124D-04	-1.277970D-02	2.102965D-02	-1.041555D-02
3.298900D-03	-1.257119D-01	-2.915806D-04	1.050073D-02
-5.463765D-04	-6.923601D-02	1.689977D-01	-1.739170D-03

TABLE 3.25d. TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	67,175 Lb
Airspeed	0 Kt
C.G.	Fwd
Altitude	S.L., 90°F

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
2.087866D 03	1.050000D 05	1.201000D 06	1.161000D 06
XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-1.728748D-02	6.717649D-01	1.479762D-01	3.249014D-01
5.015353D-03	7.670689D-01	-1.531715D-02	1.596436D-02
7.196979D-03	-1.287986D-01	-1.375717D-01	2.290870D-02
ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
7.210777D-03	-1.897262D-01	8.015881D-02	-7.351263D 00
1.568035D-03	-1.663432D 00	-3.987607D-03	4.991371D-03
-2.246967D-01	-1.390287D-01	-1.655529D-02	-7.152317D-01
MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
2.577162D-03	-2.368471D-02	1.830993D-01	-8.558422D-02
-7.172594D-05	-6.955799D-01	2.540094D-04	-2.293108D-04
-2.943096D-03	-2.295989D-01	5.805100D-03	-9.368166D-03
YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-5.440294D-03	-1.158031D 00	-2.083059D-02	4.275381D-02
-3.182515D-01	7.519164D-01	1.126989D 00	-1.013026D 00
8.803195D-04	-2.356128D-02	5.188323D-02	2.802144D-03
LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-1.760619D-03	-7.127346D-01	-2.340235D-02	3.785431D-03
-1.620633D-02	4.613560D-01	4.369419D-01	-5.158633D-02
5.650576D-04	6.891682D-02	-2.628515D-01	1.798634D-03
NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-1.313911D-04	-3.643599D-03	2.077611D-02	-8.863067D-03
1.994799D-03	-1.239308D-01	1.300654D-04	6.349642D-03
-4.087579D-04	-6.788380D-02	1.707880D-01	-1.301117D-03

TABLE 3.25a TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	67,175 Lb
Airspeed	0 Kt
C.G.	Aft
Altitude	S.L., 90°F

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
1.326483D 03	7.200000D 04	1.061000D 06	1.021000D 06

XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-5.451897D-02	-1.960226D-01	-1.961217D-02	1.592616D 00
-4.655962D-05	2.130884D 00	-6.351535D-03	-1.336870D-02
8.956366D-02	2.076890D-02	-1.338899D-01	2.571648D 01

ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
5.0287610-02	4.625416D 00	1.155292D 00	-1.635216D 01
1.951278D-02	-1.259981D 01	-6.966986D-02	5.602719D 00
-8.797731D-01	-3.908290D-02	1.569449D-01	-2.526100D 02

MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
9.246109D-05	1.328898D-01	3.142130D-01	-1.212317D-01
2.062963D-05	-1.594415D 00	-3.170652D-03	5.923403D-03
-4.406301D-03	-2.409222D-01	1.253949D-02	-1.265185D 00

YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-1.736859D-03	-2.844477D-01	-4.440428D-02	-2.396577D-01
-1.833796D-01	4.645059D-01	1.034715D 00	-5.265393D 01
-5.941082D-03	-9.341482D-02	1.985525D-01	-1.705868D 00

LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-6.755676D-04	-6.325498D-01	2.273189D-02	-1.258939D-01
-1.864200D-02	1.172969D-01	4.500971D-01	-5.352693D 00
-3.277027D-03	-1.351470D-02	-2.039100D-01	-9.409354D-01

NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-6.790698D-05	3.730374D-03	1.248858D-02	-8.652316D-03
2.249451D-03	-6.043443D-02	3.342028D-03	6.458868D-01
-3.310640D-04	-6.927613D-02	1.140592D-01	-9.505866D-02

TABLE 3.25f . TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	43,000 Lb
Airspeed	170 Kt
C.G.	Mid
Altitude	5000', STD

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
1.787158D 03	9.500000D 04	1.161000D 06	1.121000D 06
XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-3.793665D-02	1.529773D-02	-3.256938D-02	6.618385D-01
8.960024D-04	2.337746D 00	-1.339588D-02	2.419613D-01
4.806976D-02	3.916076D-02	-1.622553D-01	1.298101D 01
ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
2.370005D-02	3.259827D 00	8.485737D-01	-1.175485D 01
1.751101D-02	-1.067472D 01	-4.227919D-02	4.728765D 00
-6.307238D-01	-6.698596D-02	1.654301D-01	-1.703240D 02
MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
1.466119D-04	1.268994D-01	2.800497D-01	-1.444297D-01
2.175929D-04	-1.453638D 00	-4.768731D-03	5.875995D-02
-5.646939D-03	-2.489482D-01	1.058755D-02	-1.524929D 00
YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-2.494622D-03	-9.927384D-01	-8.730229D-02	-3.003105D-01
-1.324942D-01	6.665796D-01	1.007864D 00	-3.577944D 01
-9.816171D-03	-1.698541D-01	2.970827D-01	-2.651351D 00
LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-6.497138D-04	-6.363755D-01	9.570753D-03	-1.062941D-01
-1.641045D-02	1.424013D-01	3.969665D-01	-4.431566D 00
-2.581274D-03	-9.566972D-03	-1.731059D-01	-6.970610D-01
NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-3.782521D-05	-8.342535D-03	5.713066D-03	-1.341408D-02
2.302743D-03	-2.979951D-02	1.802979D-03	6.718451D-01
-6.544680D-04	-6.633664D-02	1.338468D-01	-1.707360D-01

TABLE 3.25g. TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	57,500 Lb
Airspeed	160 Kt
C.G.	Fwd
Altitude	5000', STD

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
1.787158D 03	9.500000D 04	1.161000D 06	1.121000D 06

XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-3.829855D-02	3.149131D-01	6.476482D-02	6.042572D-01
1.487679D-03	1.773113D 00	-4.852920D-03	4.017845D-01
4.478029D-02	5.002691D-02	-1.644819D-01	1.209403D 01

ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
2.355379D-02	3.280564D 00	8.106575D-01	-1.171430D 01
1.523072D-02	-8.039999D 00	-5.853009D-02	4.113434D 00
-6.303270D-01	-2.602089D-01	1.796135D-01	-1.702355D 02

MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
-2.770440D-04	9.509712D-02	2.715946D-01	-5.408867D-02
-1.554075D-04	-1.350672D 00	-4.848948D-03	-4.197166D-02
-1.009606D-03	-2.500264D-01	1.196007D-02	-2.726691D-01

YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-1.845317D-03	-1.076090D 00	-4.803719D-02	-2.226969D-01
-1.330380D-01	6.578458D-01	1.018112D 00	-3.593021D 01
-5.255255D-03	-1.951703D-01	-8.682088D-03	-1.419312D 00

LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-8.686923D-04	-6.851566D-01	1.493213D-02	-9.700011D-02
-1.697190D-02	1.716775D-01	4.106220D-01	-4.583683D 00
-2.181695D-03	-2.151235D-02	-2.371575D-01	-5.892209D-01

NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-3.945455D-05	3.473160D-03	6.599274D-03	-1.124011D-02
1.505687D-03	-3.840454D-02	1.830003D-03	4.066483D-01
-3.356699D-04	-6.618321D-02	1.370660D-01	-9.065600D-02

TABLE 3.25h . TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	57,500 Lb
Airspeed	160 Kt
C.G.	Aft
Altitude	5000', STD

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
2.087866D 03	1.0500000 05	1.2010000 06	1.1610000 06

XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-3.141456D-02	2.015993D-01	-1.392391D-02	2.516447D-01
2.113630D-03	2.167139D 00	-1.652513D-02	5.349983D-01
2.616320D-02	6.160091D-02	-1.736416D-01	6.622383D 00

ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
7.852932D-03	2.655278D 00	6.975207D-01	-9.666114D 00
1.493678D-02	-8.851631D 00	-3.803975D-02	3.780771D 00
-5.179932D-01	-4.838311D-02	1.935008D-01	-1.311135D 02

MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
3.383074D-05	1.077954D-01	2.591844D-01	-1.226163D-01
7.338846D-05	-1.367536D 00	-6.406043D-03	1.857596D-02
-4.407400D-03	-2.612092D-01	1.033960D-02	-1.115593D 00

YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-2.890716D-03	-1.288994D 00	-8.938804D-02	-2.864663D-01
-1.095471D-01	7.187695D-01	1.016058D 00	-2.772836D 01
-9.033832D-03	-2.192276D-01	2.620579D-01	-2.286627D 00

LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-9.480199D-04	-6.946040D-01	2.812273D-03	-9.925855D-02
-1.614931D-02	1.764652D-01	4.019138D-01	-4.087683D 00
-2.029669D-03	-9.936607D-03	-1.874372D-01	-5.137462D-01

NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR.	NDELR	NALPHA
-7.204020D-05	-8.530133D-03	4.653937D-03	-1.496525D-02
2.037820D-03	-2.064901D-02	1.122171D-03	5.158092D-01
-8.862075D-04	-6.924774D-02	1.520857D-01	-2.243153D-01

TABLE 3.251. TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	67,175 Lb
Airspeed	150 Kt
C.G.	Fwd
Altitude	5000', STD

STABILITY DERIVATIVES OUTPUT

MASS	IXX	IYY	IZZ
2.087866D 03	1.050000D 05	1.201000D 06	1.161000D 06

XU	XP	XDELB	XDELTAC
XV	XQ	XDELS	XBETA
XW	XR	XDELR	XALPHA
-3.112932D-02	3.382552D-01	3.378208D-02	2.170996D-01
2.648555D-03	1.852198D 00	-7.920439D-03	6.704157D-01
2.643363D-02	5.167624D-02	-1.679409D-01	6.691016D 00
ZU	ZP	ZDELB	ZDELTAC
ZV	ZQ	ZDELS	ZBETA
ZW	ZR	ZDELR	ZALPHA
8.392713D-03	2.648192D 00	6.713061D-01	-9.644228D 00
1.286926D-02	-7.588155D 00	-4.715279D-02	3.257533D 00
-5.173148D-01	-1.500982D-01	2.019524D-01	-1.309454D 02
MU	MP	MDELB	MDELTAC
MV	MQ	MDELS	MBETA
MW	MR	MDELR	MALPHA
-1.766695D-04	9.217588D-02	2.546711D-01	-7.369116D-02
-2.041470D-04	-1.309273D 00	-6.503844D-03	-5.167473D-02
-1.937283D-03	-2.589411D-01	1.125109D-02	-4.903750D-01
YU	YP	YDELB	YDELTAC
YV	YQ	YDELS	YBETA
YW	YR	YDELR	YALPHA
-2.774166D-03	-1.306442D 00	-7.226192D-02	-2.489999D-01
-1.099728D-01	7.808152D-01	1.015384D 00	-2.783689D 01
-7.577639D-03	-2.120051D-01	8.193440D-02	-1.918091D 00
LU	LP	LDELB	LDELTAC
LV	LQ	LDELS	LBETA
LW	LR	LDELR	LALPHA
-1.042901D-03	-7.143697D-01	5.129913D-03	-9.200405D-02
-1.659538D-02	2.075238D-01	4.085414D-01	-4.200835D 00
-1.968776D-03	-1.220763D-02	-2.283880D-01	-4.983467D-01
NU	NP	NDELB	NDELTAC
NV	NQ	NDELS	NBETA
NW	NR	NDELR	NALPHA
-4.319566D-05	-5.139474D-03	5.459906D-03	-1.577602D-02
1.664415D-03	-2.786804D-02	1.278546D-03	4.213051D-01
-6.910003D-04	-6.916679D-02	1.541899D-01	-1.749095D-01

TABLE 3.25j. TANDEM HELICOPTER STABILITY DERIVATIVES

Gross Weight	67,175 Lb
Airspeed	150 Kt
C.G.	Aft
Altitude	5000', STD

3.4.2 Tilt Rotor Flying Qualities

The stability and control data presented in volume 1 for the tilt rotor aircraft are based upon calculated aircraft derivative data. The contribution of the airframe to the derivatives has been estimated using DATCOM and the R.Ae.S. data sheets. The rotor contributions are based upon scaled M-222 test data and calculated data to extrapolate test experience. The computer programs used in this extrapolation are D-88 and C-41.

The longitudinal derivatives for the design point aircraft are given in Table 3.26 and include the effect of wing-rotor interference.

The rotor data used in calculation of yaw and yaw rate derivatives are shown in Tables 3.28 to 3.33 the airplane lateral derivative data is given in Tables 3.34 to 3.36.

ALT = 0
G.W. = 274,750
C.G. @ 25%

V	C_{L_α} (per deg)	C_{M_α} (per deg)		$C_{M_{\dot\alpha}}$ (per rad/sec)	C_{m_q} (per rad/sec)
140	.1434	-.0209	39.55	-27.22	-83.25
180	.1481	-.0275	43.57	-24.55	-82.21
220	.1523	-.0319	45.92	-24.45	-81.84
260	.1545	-.0379	49.56	-24.88	-82.55
300	.1561	-.0450	53.83	-25.82	-84.16
340	.1601	-.0529	58.06	-26.98	-86.61
380	.1675	-.0616	61.76	-28.40	-90.09
C.G. @ 34%					
140	.1434	-.0080	39.55	-26.25	-80.94
180	.1481	-.0142	43.57	-23.68	-79.83
220	.1523	-.0182	45.92	-23.58	-79.39
260	.1545	-.0240	49.56	-23.99	-79.97
300	.1561	-.0309	53.83	-24.90	-81.44
340	.1601	-.0385	58.06	-26.02	-83.72
380	.1675	-.0465	61.76	-27.39	-87.00
G.W. = 60,000 C.G. @ 10%					
140	.1426	-.0422	39.63	-28.87	-87.22
180	.1478	-.0497	43.61	-26.05	-86.27
220	.1522	-.0547	45.94	-25.94	-86.04
260	.1545	-.0611	49.57	-26.39	-86.95
300	.1560	-.0684	53.84	-27.40	-88.80
340	.1600	-.0769	58.06	-28.62	-91.55
380	.1674	-.0867	61.77	-30.13	-95.37

TABLE 3.26. LONGITUDINAL DERIVATIVES AS FUNCTION OF ALTITUDE, GROSS WEIGHT, AND C.G. LOCATION

ALT = 14000'
G.W. = 74,750
C.G. @ 34%

V	C_{L_α}	C_{M_α}	NP%	$C_{M_{\dot{\alpha}}}$	C_{m_q}
140	.1480	-.0061	38.09	-26.25	-81.70
180	.1510	-.0124	42.21	-23.68	-80.42
220	.1547	-.0165	44.67	-23.58	-79.83
260	.1566	-.0226	48.43	-23.99	-80.30
300	.1578	-.02°8	52.87	-24.90	-81.67
340	.1616	-.0376	57.29	-26.02	-83.88
380	.1687	-.0459	61.19	-27/39	-87.10

G.W. = 60,000
C.G. @ 10%

V	C_{L_α}	C_{M_α}	NP%	$C_{M_{\dot{\alpha}}}$	C_{m_q}
140	.1461	-.0413	38.26	-28.87	-87.94
180	.1503	-.0485	31.32	-26.05	-86.82
220	.1544	-.0536	44.70	-25.94	-86.44
260	.1565	-.0602	48.45	-26.39	-87.24
300	.1578	-.0677	52.89	-27.40	-89.01
340	.1615	-.0764	57.30	-28.62	-91.68
380	.1687	-.0864	61.20	-30.13	-95.44

TABLE 3.26. LONGITUDINAL DERIVATIVES AS FUNCTION OF ALTITUDE, GROSS WEIGHT, AND C.G. LOCATION (Continued)

1985 T/R VTOL C.T.

Sea Level — Rotor (includes circulation effects)

V	F_{X_α}	F_{Y_α}	M_{Y_α}	$M_{Y_{\dot\alpha}}$	M_{X_α}
140	576	106	1884	-1878	9,150
180	1136	0	1946	-1745	17,140
220	1834	-168	1265	-1465	23,500
260	2439	-400	168	-1172	26,600
300	2900	-677	-1858	- 919	27,750
340	3250	-970	-5120	- 650	28,050
380	3450	-1294	-9400	- 380	27,400
	lb/deg	lb/deg	ft lb/deg	ft/lb/ deg/sec	ft lb/sec

Airframe Rotor Off

V	$C_{L_{\alpha WBN}}$	$C_{L_{\alpha T}}$	$C_{M_{\alpha WB}}$
140	.1032	.0773	.0265
180	.1035	.0791	.0265
220	.1053	.0812	.0265
260	.1085	.0839	.0265
300	.1125	.0871	.0265
340	.1190	.0910	.0265
380	.1288	.0958	.0265

TABLE 3.27 . BASELINE TILT ROTOR LONGITUDINAL DERIVATIVES

C_{n_r} Rotors On

140	-1.3492	-1.3429	-1.3194	-1.4655	-1.4031
180	-1.0738	-1.0703	-1.0617	-1.1355	-1.1113
220	- .9135	- .9125	- .9087	- .9537	- .9435
260	- .8068	- .8074	- .8054	- .8458	- .8317
300	- .7424	- .7434	- .7423	- .7660	- .7644
340	- .7000	- .7016	- .7009	- .7209	- .7211
380	- .6739	- .6759	- .6755	- .6939	- .6953

TABLE 3.28 . C_{n_r} DERIVATIVES

C_{ℓ_r} Rotors On

140	.7287	.7338	.6061	.9714	.7795
180	.5400	.5388	.4621	.6917	.5717
220	.4323	.4279	.3769	.5373	.4536
260	.3387	.3320	.2957	.4644	.3515
300	.2800	.2723	.2452	.3385	.2879
340	.2430	.2343	.2132	.2898	.2476
380	.2175	.2084	.1914	.2567	.2203

TABLE 3.29. C_{ℓ_r} DERIVATIVES (RADIAN MEASURE)

C_{y_r} Rotors On

140	.9022	.9566	.9566	.8877	.9455
180	.8576	.9114	.9114	.8415	.8987
220	.8313	.8834	.8834	.8151	.8705
260	.8461	.8946	.8946	.8318	.8834
300	.8945	.9395	.9395	.8858	.9336
340	.9681	1.0057	1.0057	.9668	1.0067
380	1.0417	1.0735	1.0735	1.0485	1.0823

TABLE 3.30. C_{y_r} DERIVATIVES (RADIAN MEASURE)

C_{n_p} Rotors On

140	-.4026	-.4072	-.3544	-.5100	-.4337
180	-.3611	-.3611	-.3293	-.4334	-.3845
220	-.3146	-.3116	-.2904	-.3673	-.3316
260	-.2633	-.2582	-.2432	-.3032	-.2748
300	-.2212	-.2047	-.2035	-.2524	-.2284
340	-.1893	-.1820	-.1734	-.2144	-.1936
380	-.1640	-.1562	-.1495	-.1847	-.1662

TABLE 3.31. C_{n_p} DERIVATIVES (RADIAN MEASURE)

C_{ℓ_p} Rotors On

140	-1.0460	-1.0468	-1.0436	-1.0898	-1.0803
180	-1.1455	-1.1455	-1.1435	-1.1876	-1.1830
220	-1.2017	-1.2015	-1.1992	-1.2451	-1.2414
260	-1.1862	-1.1861	-1.1833	-1.2282	-1.2246
300	-1.1402	-1.1402	-1.1369	-1.1797	-1.1759
340	-1.0921	-1.0922	-1.0888	-1.1296	-1.1258
380	-1.0456	-1.0457	-1.0421	-1.0818	-1.0779

TABLE 3.32. C_{ℓ_p} DERIVATIVES (RADIAN MEASURE)

C_{y_p} Rotors On

140	.2882	.2882	.2514	.3634	.3070
180	.0722	.0722	.0500	.1116	.0769
220	-.0605	-.0605	-.0753	-.0417	-.0644
260	-.1503	-.1503	-.1608	-.1438	-.1600
300	-.2095	-.2095	-.2173	-.2111	-.2231
340	-.2426	-.2426	-.2487	-.2490	-.2623
380	-.2645	-.2045	-.2693	-.2744	-.2817

TABLE 3.33. C_{y_p} DERIVATIVES (RADIAN MEASURE)

C_{n_β} Rotors On

140	+.00595	.00686	.00686	.00588	+.00681
180	+.00692	.00718	.00718	.00618	.00715
220	.00661	.00759	.00759	.00661	.00762
260	.00108	.00808	.00808	.00711	.00813
300	.00715	.00850	.00850	.00759	.00862
340	.00803	.00900	.00900	.00818	.00918
380	.00858	.00954	.00954	.00880	.00978

TABLE 3.34. C_{n_β} DERIVATIVES (PER DEGREE)

C_{ℓ_β} Rotors On

140	-.00482	-.00460	-.00476	-.00454	-.00449
180	-.00381	-.00342	-.00371	-.00357	-.00348
220	-.00310	-.--3-4	-.00298	-.00290	-.00278
260	-.00249	-.00245	-.00237	-.00227	-.00217
300	-.00221	-.00219	-.00210	-.00201	-.00191
340	-.00204	-.00204	-.00195	-.00186	-.00177
380	-.00198	-.00199	-.00190	-.00180	-.00174

TABLE 3.35. C_{ℓ_β} DERIVATIVES (PER DEGREE)

C_{Y_β} Rotors On

140	-.04217	-.04217	-.04217	-.04288	-.04288
180	-.04394	-.04394	-.04394	-.04479	-.04479
220	-.04494	-.04494	-.04494	-.04588	-.04588
260	-.04511	-.04511	-.04511	-.04610	-.04610
300	-.04512	-.04512	-.04512	-.04615	-.04615
340	-.04435	-.04435	-.04435	-.04538	-.04538
380	-.04374	-.04374	-.04374	-.04479	-.04479

TABLE 3.36. C_{Y_β} DERIVATIVES (PER DEGREE)

3.4.3 Tilt Rotor

A. GUST SENSITIVITY REDUCTION BY DIRECT LIFT CONTROL

A.1 BACKGROUND

The one hundred passenger tilt rotor VTOL transport is to be evaluated against the gust sensitivity criteria which requires that the incremental normal acceleration factor per feet per second of vertical gust should not exceed a value of .018 at 10,000 feet, growing in approximately linear manner to an allowable A_n/U_{DE} of .037 at 30,000 feet. It was recognized in the study guidelines that unless special measures were taken a tilt rotor transport would probably have aerodynamic characteristics which tended to produce gust sensitivities above these criteria. Since the tilt rotor transport will operate at relatively lower altitudes and therefore in a more severe turbulence environment then most other types of passenger carrying aircraft, a gust alleviation system based on direct lift control is probably an essential feature for passenger acceptance.

A.2 BASIC CHARACTERISTICS

Evaluation of the subject designs (Figure I) at 10,000 feet and at 14,000 feet, the optimal cruise altitude indicates that the criterion is exceeded even at maximum operating gross weight, while values of A_n/U_{DE} greater than 0.05 are attained at the most likely minimum operating gross weight

(minimum fuel, ten passengers). These are conservative results obtained using FAR 25-341 which addresses limit load gust conditions rather than ride quality evaluations. A preliminary study has been made of the requirements of flap and spoiler operation to reduce gust sensitivity to the criterion levels. The study indicates that this may be accomplished with no significant weight penalty since the flap and spoiler excursions estimated for this purpose fall well inside the range envisioned for roll control.

A.3 APPROACH TO GUST ALLEVIATION

The conclusions in the study are based on the formulae given in the Federal Aviation Regulations, Volume III, Part 25, Paragraph 25-341 and on MIL-F-8785B (ASG). The normal acceleration produced by a gust increases with the aircraft lift curve slope and reduces with wing loading. Since wing loading is fixed by other considerations in the design point aircraft, lift curve slope is the parameter which must be modified to control gust sensitivity. This may be accomplished by the application of flap or spoiler in proportion to change in angle of attack caused by the gust. The system required to do this is defined by:

(a) Gain: Ratio of flap or spoiler applied per unit
• Change in angle of attack caused by a gust.

(b) Authority: What level of gust will the system be designed to handle?

(c) Rotor or Frequency Response: How fast does the system need to act?

These parameters have been evaluated for critical conditions of aircraft weight and altitude, and conservative assumptions have been made at each stage. Gains have been selected on the basis of the FAR formulae while gust intensity and wavelength is based on MIL-F-8785 B (ASG)

Gain:

At a minimum operating gross weight of 55,726 pounds at 10,000 feet and a maximum cruise speed of 296.5 knots EAS a net lift curve slope of .05 per degree is required to reduce A_n/U_{DE} to a value of .018. This is a reduction of .116/degree to be provided by geared spoiler or flap operation. The flap and spoiler lift curve slope characteristics are $\frac{dC_L}{d\beta_F}$ .025 and .014 per degree respectively. Assuming the presence of a system which applies flap or spoiler in proportion to aircraft angle of attack, flap or spoiler contributions to net $\frac{dC_L}{d\alpha}$ is given by

$$\Delta \frac{dC_L}{d\alpha} = \frac{dC_L}{d\beta_F} \cdot \frac{d\beta_F}{d\alpha}$$

$$= \frac{dC_{L_X}}{d\beta_F}$$

Thus the required gains are

$G_{FLAP} = \frac{.116}{.025} = 4.64$ degrees per degree of gust induced angle of attack

and $G_{SPOILER} = \frac{.116}{.014} = 8.03$ degrees per degree of gust induced angle of attack

At higher values of gross weight these gains will result in values of A_n/U_{de} substantially smaller than .013. It should be noted that the FAR 25, Paragraph 25.341 formulae are for structural type gust frequencies so that better performance may also be expected when typical turbulence spectra are associated with these gains.

Authority:

Making the conservative assumption that there is no reduction in incremental angle of attack when the direct lift control is working, the flap or spoiler angle demanded is

$$\beta = G. \Delta \alpha$$

$$= G. \frac{U_{DE}}{V_{TAS}} \quad \text{radians.}$$

In the case being discussed V_{TAS} = 586 feet per second so that

$$\beta_F = 4.62 \times \frac{U_{DE}}{584} \times 57.3 \text{ degrees}$$

$$= .455\ U_{DE}$$

and $$\beta_{SPOILER} = \frac{8.03 \times U_{DE} \times 57.3}{584}$$

$$= 0.79\ U_{DE}$$

Discrete Gust Representation

Following MIL F-8785B(ASG) it was estimated that Dryden scale random turbulance may be represented by discrete gust intensities in the range 10-15 feet per second at frequencies in the range of the short period mode. Such gust levels require authorities of

$$\beta_{FLAP} = 4.55 \text{ to } 6.8 \text{ degrees}$$

$$\beta_{SPOILER} = 7.9 \text{ to } 12 \text{ degrees}$$

which are substantially less than the 20 degrees of flap and 45 degrees of spoiler provided for roll control.

Rate of Operation

A gust tuned to the highest frequency short period has a length of approximately 255 feet. Assuming a (1-cosine) wave form a 15 FT/SEC gust produces a maximum rate of change of angle of attack of 10.6 degrees per second. Hence maximum rate of application of flap and spoiler required are

$$\beta_{FLAP} = 4.64 \times 10.6 \approx 50 \text{ degrees/second}$$

$$\beta_{SPOILER} = 8.03 \times 10.6 \approx 85 \text{ degrees /second}$$

Installed Control Power

The controls of the one hundred passenger transport are designed to meet a time constant requirement of 0.2 seconds. (Paragraph 4.1.1.3 Study Guidelines). This requires average rates of operation of flap and spoiler of at least

$$\beta_{FLAP} \quad \frac{.63 \times 20}{.2} \text{ degrees/second} = 63 \text{ degs/second}$$

$$\beta_{SPOILER} \quad \frac{.63 \times 45}{.2} \text{ degrees/second} = 142 \text{ degs/second}$$

Thus the installed rates of operation are more than adequate to provide the maximum rates of operation demanded by a direct lift control system.

Conclusions Regarding Direct Lift Control for Gust Sensitivity Reduction

It is concluded that the control applications required to reduce gust sensitivity to within the criteria values are available in the basic design and that the introduction of a DLC system would not incur significant structural load or control power penalties. The only major additional system requirements and weight penalties would be those associated with gust sensing equipment and avionics for signal conditioning and transmission of commands to the control surface actuators. This is estimated to be approximately 35 pounds.

3.5 COSTING METHODOLOGY

Flyaway Costs

The airframe costs were calculated using factors of \$90.00 and \$110.00 per pound of airframe. The airframe weight was arrived at as follows:

Tilt Rotor

Airframe = Empty Weight - $(W_P + W_{DR} + W_{EN} + W_{AV})$

Helicopter

Airframe = Empty Weight - $(W_R + W_{DR} + W_{EN} + W_{AV})$

Where:

W_P = Weight of Props

W_{DR} = Weight of Drive System

W_{EN} = Weight of Engines

W_{AV} = Weight of Avionics

W_R = Weight of Rotors

It should be noted that in the equations used for calculating airframe maintenance costs, which use airframe weight, the weight of the avionics systems was included in the airframe since the AIA methodology does not make provision for calculating avionics maintenance cost as a separate item.

Other major systems costs were calculated as shown below:

Cost of Dynamic System

Tilt Rotor = \$80 $(W_{DR} + W_P)$

Helicopter = \$80 $(W_{DR} + W_R)$

Cost of Engines

Tilt Rotor and Helicopter = $E_N(\$280HP^{0.785})$

where:

E_N = Number of Engines

HP = Static SHP at SL/STD for 1 engine

Cost of Avionics

Tilt Rotor or Helicopter = \$250,000

OPERATING COSTS

Direct operating costs were developed using the Aerospace Industries Association's (AIA) "Standard Method of Estimating Direct Operating Costs of Turbine Powered VTOL Transport Aircraft" dated 1968, modified as agreed on at the guideline review coordination meeting, as follows:

Crew Costs

$$\$/FH = \frac{.067 \text{ Gross Weight}}{1000} + 134$$

Engine Maintenance Costs

Labor (\$/FH) = 0.65 (AIA Costs)

Material (\$/FH) = 0.65 (AIA Costs)

Maintenance Burden

$$\$/FH = 1.5(DL_{AF} + DL_{EN} + DL_{DS})$$

Where:

DL_{AF} = Direct Labor Costs for Airframe Maintenance

DL_{EN} = Direct Labor Costs for Engine Maintenance

DL_{DS} = Direct Labor Costs for Dynamic System Maintenance

The selected utilizations, 2500 and 3500 flight hours per year, reasonably cover the values for the tilt rotor and tandem helicopter for 150 to 200 n mi average flight distances as read from the AIA utilization curve, based on block time.

The attachment to NASA Document FPV:237-2 of Appendix 1, Volume II list other factors used in calculating the direct operating costs.

Cost of Avionics

Tilt Rotor or Helicopter = $250,000

The selections of $90 to $110 per pound for airframe and $80 per pound for dynamic system together correspond to a reasonable number of production aircraft. The airframe price range also allows for uncertainty in the production costs of advanced materials used in the airframe design.

3.6 DESIGN DETAILS

This section contains data on the various aircraft systems sufficient to estimate the aircraft size, weight and performance. The systems requiring definition or configuration selection are drive system, rotor system, flight-control system and fuel system. Each of these aircraft systems are described in the following sections.

TANDEM ROTOR HELICOPTER - PROPULSION SYSTEM SELECTION

The propulsion system for the design point tandem helicopter was based upon detailed design studies and evaluations performed in the design of the HLH vehicle and reported in Reference 4 .

The final system is a three engine configuration mounted at the rear of the fuselage. One engine is located in the rear pylon and the other two on each side of the rear pylon. All three engines drive into a combiner transmission box located at the base of the rear pylon directly over the baggage compartment. The combiner transmission drives two shafts - one forward to the forward rotor transmission and one aft up the rear pylon to the aft rotor transmission. A schematic of this layout is shown in Figure 3.35.

In selecting a propulsion system configuration, there are four major areas to be examined:

1) Engine location
2) Rotor - Rotor Shafting
3) Engine - drive systems
4) Number of engines

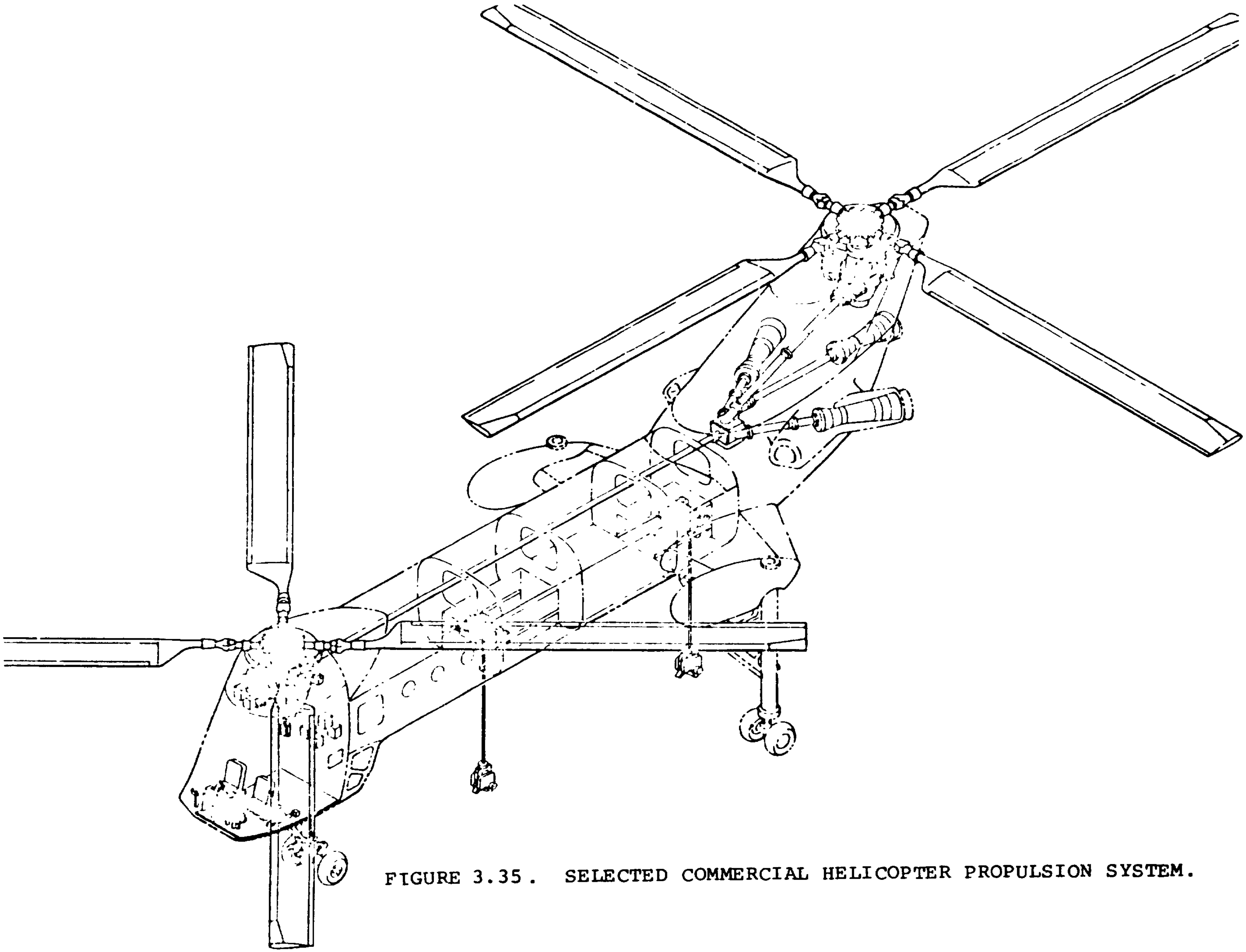


FIGURE 3.35. SELECTED COMMERCIAL HELICOPTER PROPULSION SYSTEM.

Engine location was selected by considering a wide range of possible locations and using a process of elimination.

Engines located within the primary fuselage structure were eliminated because of the complex fire walls required, difficult engine access and safety problems posed by engine failure modes.

Engines located on the upper fuselage were rejected on crash-worthiness grounds. In a crash with inertia loads, primarily down and forward, engine masses might separate from their mounts and penetrate the passenger cabin.

Aft engine mounting arrangements are far superior from a crashworthiness standpoint since their crash separation trajectories have much less chance of infringing on occupied areas and engine fires are as far removed from passengers and crew as possible.

The engine location decision was based upon these considerations and, in addition, aft engine location minimizes engine noise and vibration in the passenger area.

<u>Rotor to Rotor Shafting and Engine Drive System</u>

Three different rotor to rotor shafting layouts were considered as shown schematically in Figure 3.36.

The relative complexity of these systems was evaluated (without engine input gearing). Option C is superior (2gear boxes, 30 gears). This version, however, would require either an integrally lubricated support bearing for the aft shaft or lubrication lines up the aft pylon. Option B is next least

OPTION A
- NO. BOXES 3
- NO. GEARS 32
- NO. GEARS BETWEEN PLANETARIES 6
- NO. GEAR MESHES BETWEEN PLANETARIES 3
- WEIGHT INDEX NUMBER 1.00

OPTION B
- NO. BOXES 3
- NO. GEARS 30
- NO. GEARS BETWEEN PLANETARIES 4
- NO. GEAR MESHES BETWEEN PLANETARIES 2
- WEIGHT INDEX NUMBER 1.00

OPTION C
- NO. BOXES 2
- NO. GEARS 30
- NO. GEARS BETWEEN PLANETARIES 4
- NO. GEAR MESHES BETWEEN PLANETARIES 2
- WEIGHT INDEX NUMBER 1.05

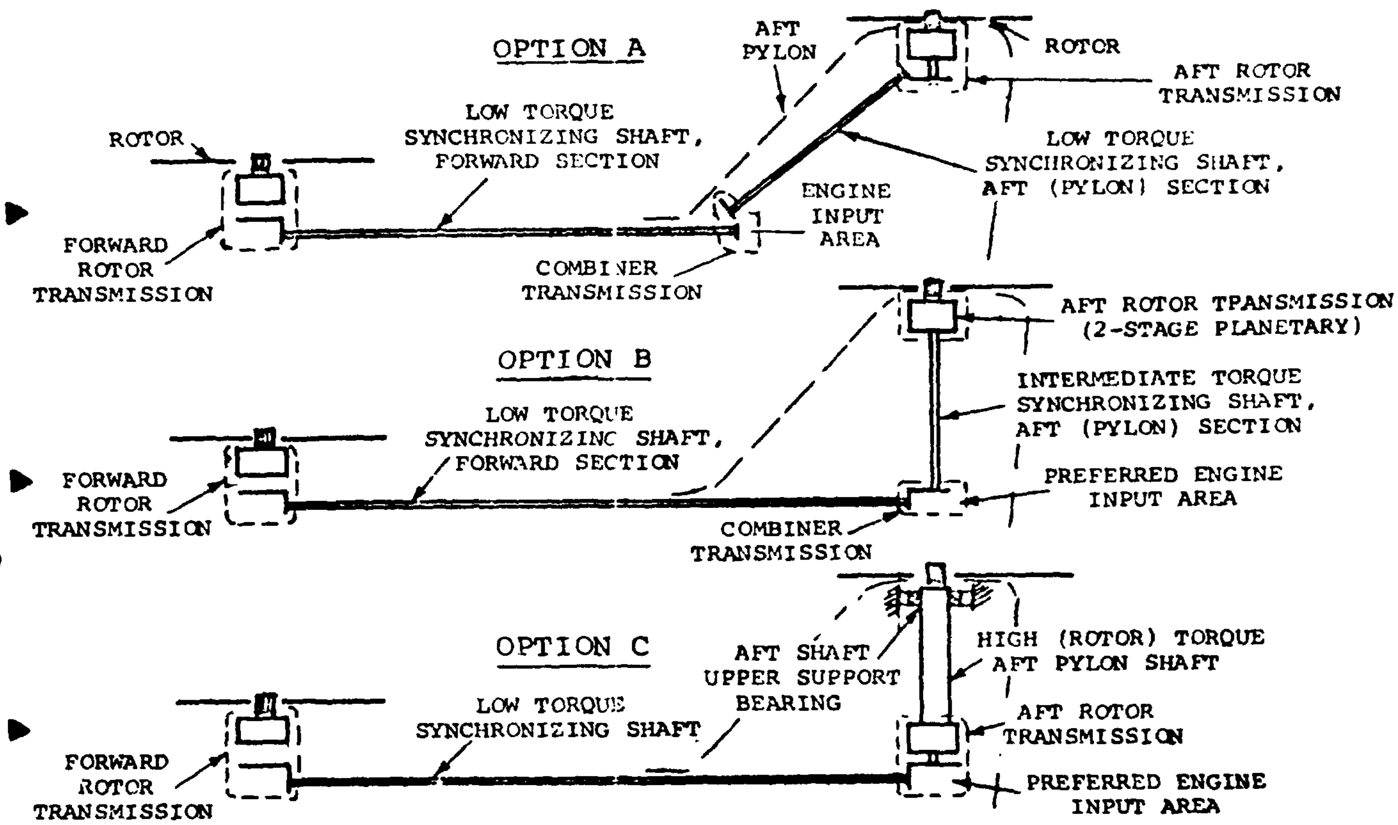


Figure 3.36. Rotor-to-Rotor Shafting Concepts Definitions

complex (3 boxes, 30 gears), and Option A last (3 boxes, 32 gears). System weight was considered, giving Option A and B equal weight and Option C 5% heavier. Option A is best from a CG standpoint since it provides the most forward CG. A further advantage of Option A becomes apparent when the engines are added to the system; since engines could be coupled in using a short extension aft of the forward synchronizing shaft without adding a gear box.

Options B and C require the introduction of engine gearing on the forward side of the bevel pinion.

Also, Option A allowed front drive engines to be mounted without overhanging the aft aircraft contour; Options B and C require an overhang.

Option A also rates the highest from the point of view of airframe interface problems. The combiner gear box can be simply supported from existing structure. Options B and C need added structural support.

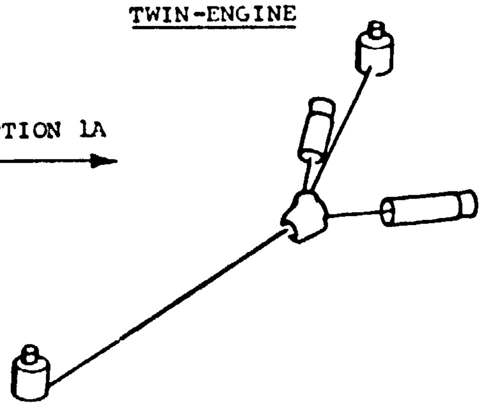
Option A was selected as the best overall system combining low weight and best center of gravity with minimum additional gear box and support structure requirements.

Engine Drive Arrangements and Number of Engines

The engine drive arrangements for two, three and four engines are shown in Table 3-37. The preferred system is Option 1a (2 engines) since it is the least complex; however, the OEI requirements for vehicle performance cause the installed power of the vehicle to increase as engine number decreases. This

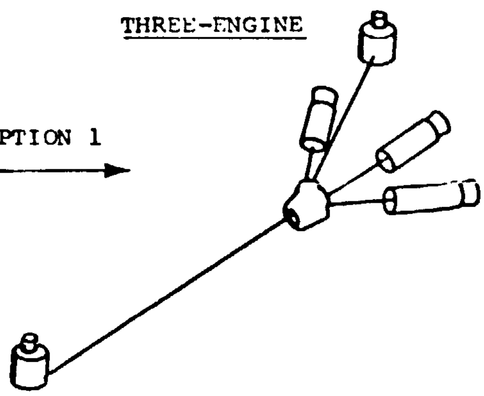
TWIN-ENGINE

OPTION 1A →



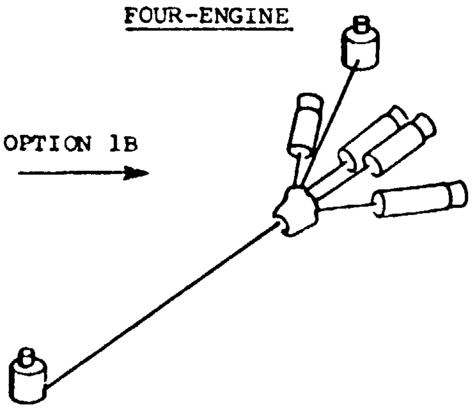
THREE-ENGINE

OPTION 1 →



FOUR-ENGINE

OPTION 1B →



	NO. BOXES	NO. GEARS	NO. SHAFTS	η_T	SYSTEM* WT FACTOR	CONFIGURATION EVALUATION
TWIN-ENGINE OPTION 1A	3	35	4	96.9	1.0	PREFERRED SYSTEM: EASIEST POWER-PLANT INSTALLATION; MINIMUM AIRFRAME INTERFACE PROBLEMS; SIMPLEST DRIVE SYSTEM
THREE-ENGINE OPTION 1	3	37	5	97.0	1.02	SECOND-CHOICE SYSTEM: POWERPLANT INSTALLATION COMPLICATED BY CENTER ENGINE INLET; TWO MORE SPUR GEARS IN DRIVE SYSTEM
FOUR-ENGINE OPTION 1B	3	38	6	96.9	0.96	LEAST DESIRABLE SYSTEM: MOST COMPLEX ENGINE INSTALLATION; THREE MORE GEARS IN DRIVE SYSTEM

* DRIVE SYSTEM AND ENGINE WEIGHT AT SAME TRANSMISSION RATING.

TABLE 3.37. COMPARISON OF SELECTED ENGINE-DRIVE ARRANGEMENTS.
AND
FIGURE 3.37

effect has a large impact on gross weight and installed power as shown in Figures 3.38 and 3.39 , but the incremental weight saved per engine decreases as engine number increases. Three engines were considered to be the best compromise resulting in the propulsion system selected for the design point tandem helicopter. This selection was made on the basis of minimum cost as shown in Figure 3.40 .

The three engines mounted aft drive directly into a combiner box as shown in the schematic of Figure 3.35 The combiner box drives two output shafts which in turn provide power input to the fore and aft rotor transmissions. The engines are rubberized versions of a Lycoming LTC4V-1 rated at a maximum power of 4820 horsepower per engine at sea level, standard day and operating at 16,000 RPM. The combiner box has an overall ratio of 1.6:1 with engine input gear critical mesh torques of 2,531 foot-pounds.

Each rotor transmission has an overall ratio of 49.75:1 and transmits a maximum of 7,953 horsepower to each rotor. This corresponds to a maximum output torque of 207,847 foot-pounds. The overall transmission efficiency is 97%.

Rotor System

The rotor selected for the tandem helicopter is fully articulated and 68.9feet in diameter. The rotor solidity is 0.099 and has a 12° twist. The design tip speed is 720 feet per second (i.e., RPM = 200.96). The rotors are four-bladed with fiberglass blades similar to the XCH-62 design. The blades incorporate a multiple load path wrap around root end

TANDEM HELICOPTER - 100 PASSENGERS
NUMBER OF ENGINES TRADE STUDY

$W/A = 9.0\ LB/FT^2$
VTIP = 725 FPS

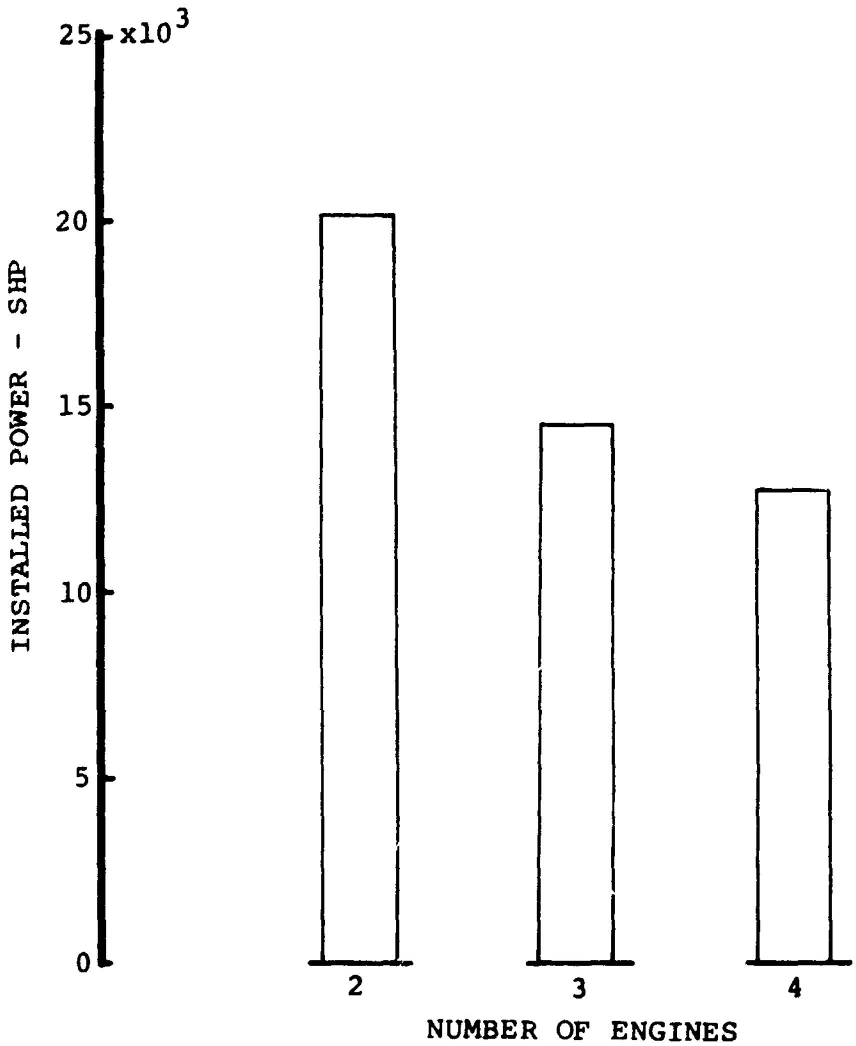


FIGURE 3.38 . NUMBER OF ENGINE TRADE - INSTALLED POWER.

TANDEM HELICOPTER - 100 PASSENGERS
NUMBER OF ENGINES STUDY

$W/A = 9.0\ LB/FT^2$

VTIP = 725 FPS

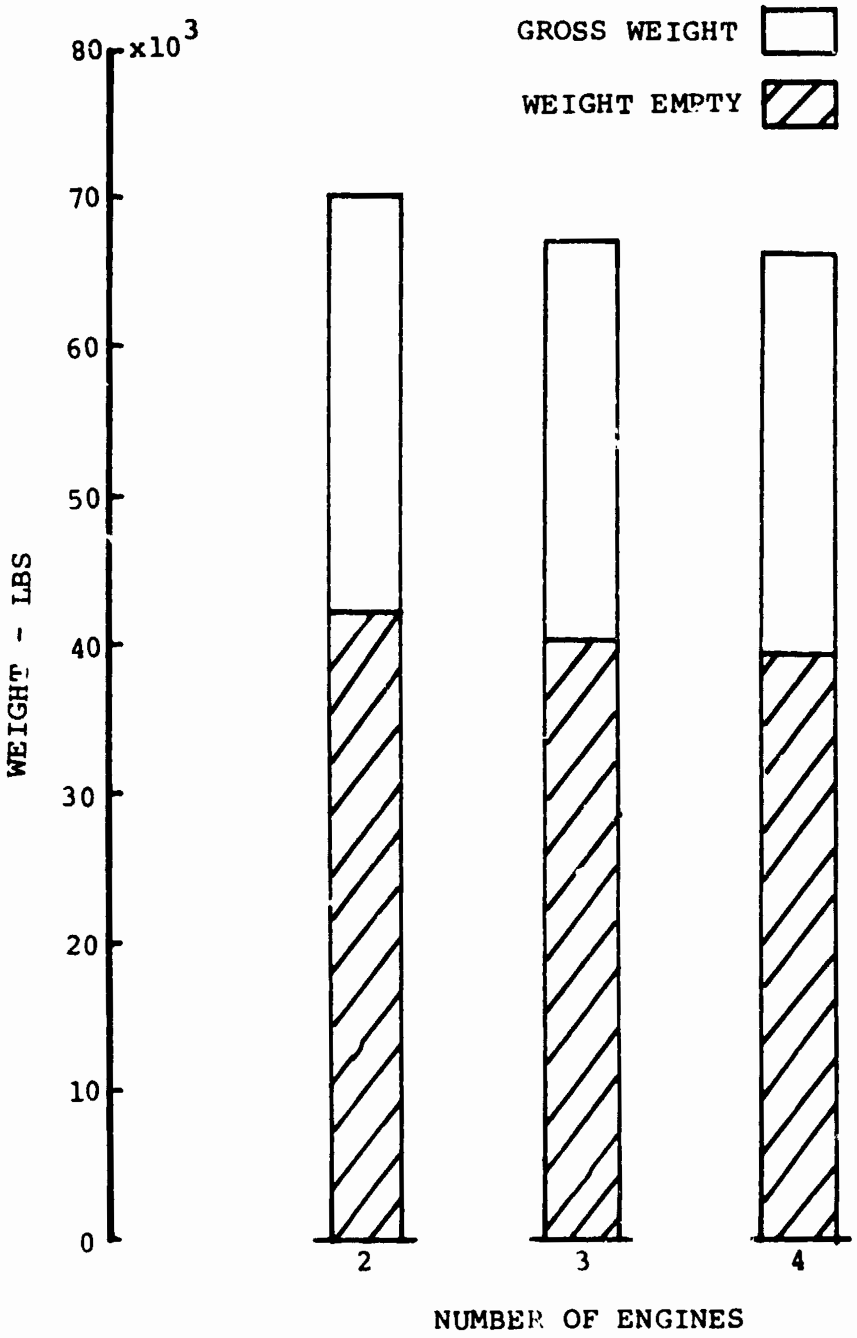


FIGURE 3.39. NUMBER OF ENGINE TRADE - GROSS WEIGHT AND WEIGHT EMPTY.

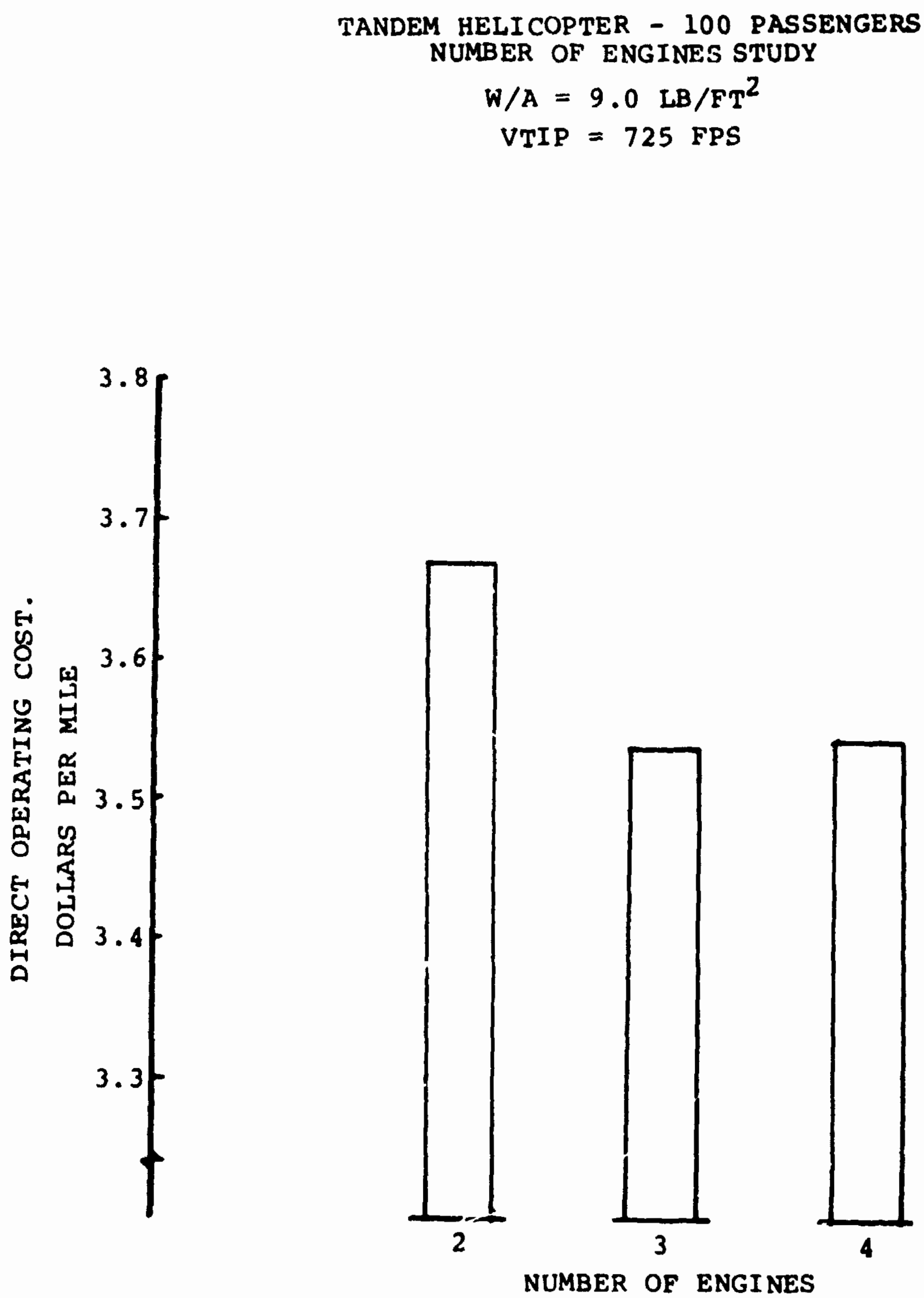


FIGURE 3.40. NUMBER OF ENGINE TRADE - DIRECT OPERATING COST.

and a fiberglass D spar. The airfoil section skins are fiberglass crossply, stiffened by Nomex honercomb core. A titanium nose cap provides leading edge erosion protection.

The blades are fitted with lightening strike protection, electrical de-ice and are estimated to have a mean time between removals of 2,000 hours.

A schematic of the hub and blade is shown in Figure 3.41.

The hub is fitted with frequency selective lag dampers.

The limiting factor on helicopter speed and maneuver load factor at high speed is generally high pitch link loads due to stall flutter. Figure 3.42 shows a semi-empirical conservative criteria for the inception of stall flutter and it has been used to size the rotor solidity to maintain an adequate maneuver margin from stall flutter. The three tandem helicopters are shown at 1 g and 1.25 g's at cruise speed.

These aircraft can pull 1.25 g's in a sustained maneuver at cruise speed without stall flutter induced loads. A maneuver load factor was not specified in the guidelines (Section4.0) and is not specified in FAR requirements. However, a maneuver capability of 1.25 g's (corresponding to a 37° banked turn capability with a turn radius of 3,227 feet at cruise speed) is considered adequate for a commercial helicopter flying in an Air Traffic Control System.

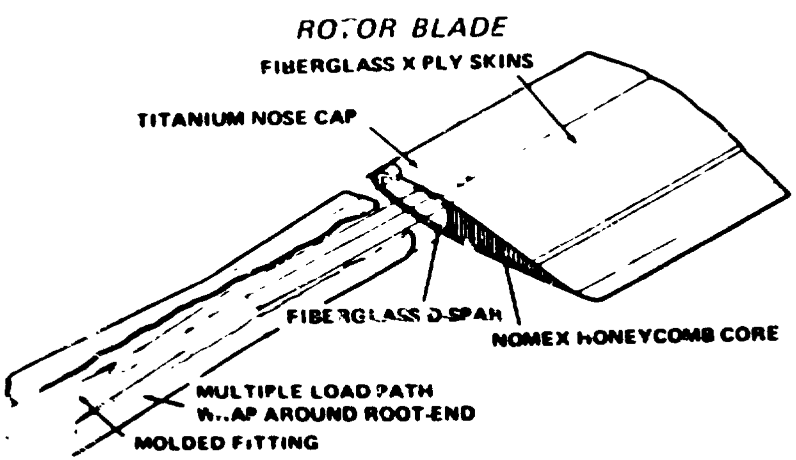
<u>Fly-By-Wire Control System</u>

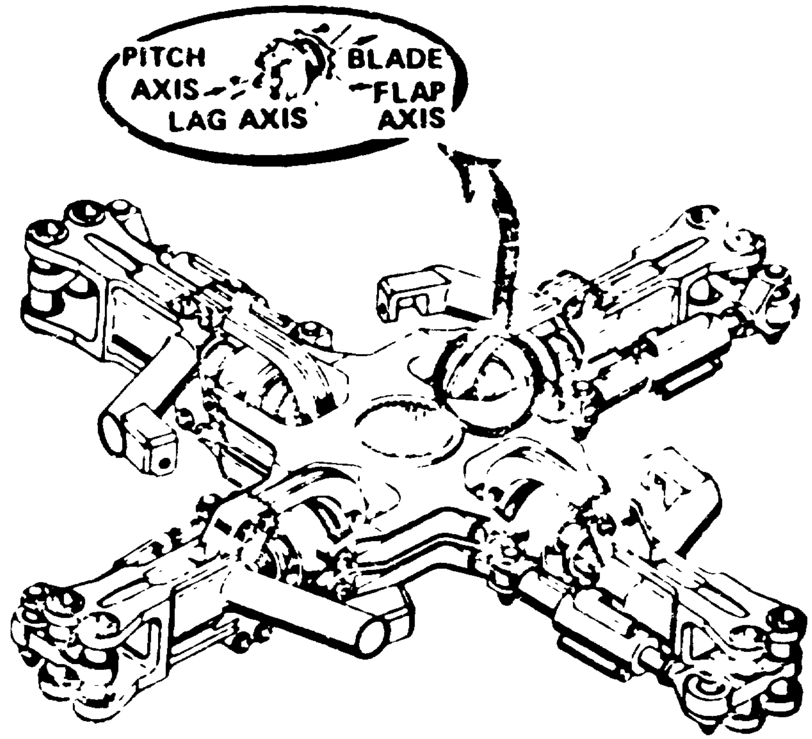
The fly-by-wire control system envisaged for the design tandem helicopter is the flight control system recently flown on the Boeing Model 347 helicopter, except that in the commercial case

- FIBERGLASS BLADES /4 BLADES
- DIAMETER 68.9 FT./
  SOLIDITY .099/V_t = 725 FPS
- LIGHTNING STRIKE PROTECTION

HUB

- TITANIUM UPPER/LOWER PLATES
- FREQUENCY SELECTIVE LAG DAMPERS





BLADES

- 32.5 IN. CHORD
- S-GLASS
- ISIS SPAR
- IN-FLIGHT TRACKING
- ELECTRICAL DE-ICE
- MTBR 2000 HOURS

FIGURE 3.41. TANDEM ROTOR HELICOPTER - ROTOR SYSTEMS.

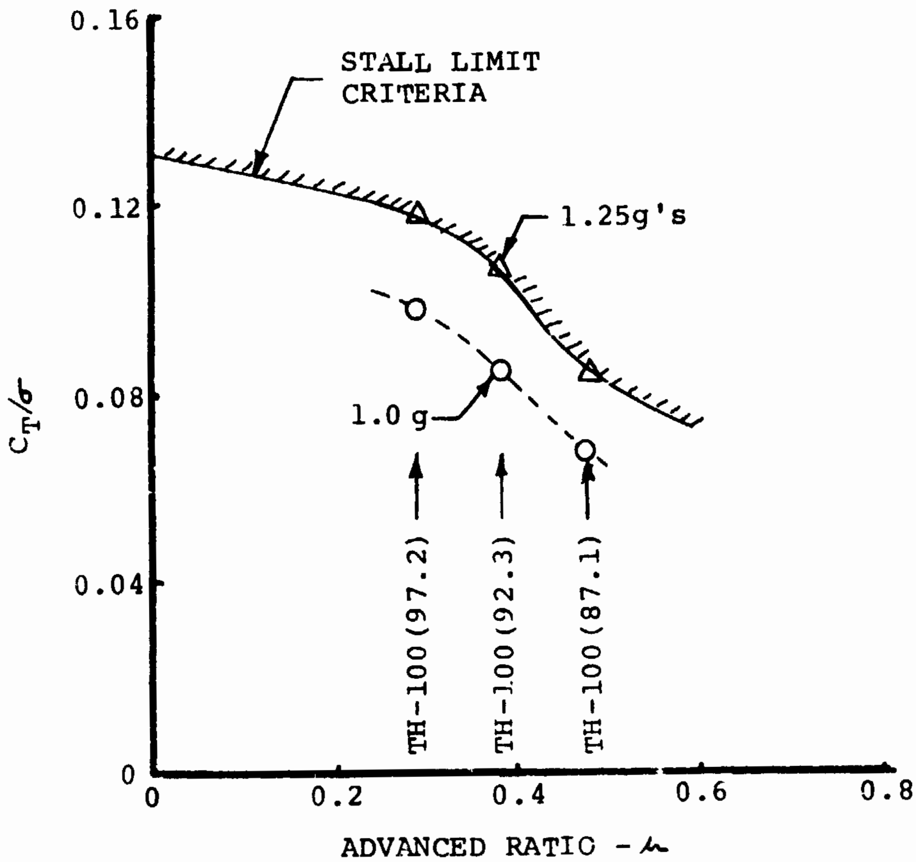


FIGURE 3.42. TANDEM HELICOPTER - SOLIDITY SIZING.

a quadruple system would be used instead of the triple redundancy of the 347 system. This additional channel provides the means to design a fail operable control system. In this context "fail operable" is intended to mean that with any single failure the pilot suffers no control degradation.

The elements and functions of the control system are listed in Table 3.38 and a basic block diagram schematic is shown in Figure 3.43.

Fuel System

The location of the fuel tanks below the aft cabin floor requires that "crashworthy" fuel cells be used. The crashworthy fuels cells used in the tandem helicopter design are based on experience with the CH-47C.

The CH-47C crashworthy fuel cells were designed and developed to meet the crashworthy requirements of MIL-T-27422B, which requires high tear resistance and the ability to meet an impact test of 65 feet per second. The cell construction is of a very high strength with a tensile strength of approximately 36,000 pounds.

To prevent the cell from tearing when installed on an aircraft when a load is applied in any direction, all hard mounting points are designed as frangible attachment. This will allow the cell to move in the compartment without rupturing.

All of the connections into the fuel lines have breakaway self-sealing valves which are designed to break when a load is applied from any direction and seal the fuel tank and the fuel lines. The part of the valve on the tank is designed

TABLE 3.38

TANDEM ROTOR HELICOPTER

FLIGHT CONTROL SYSTEMS

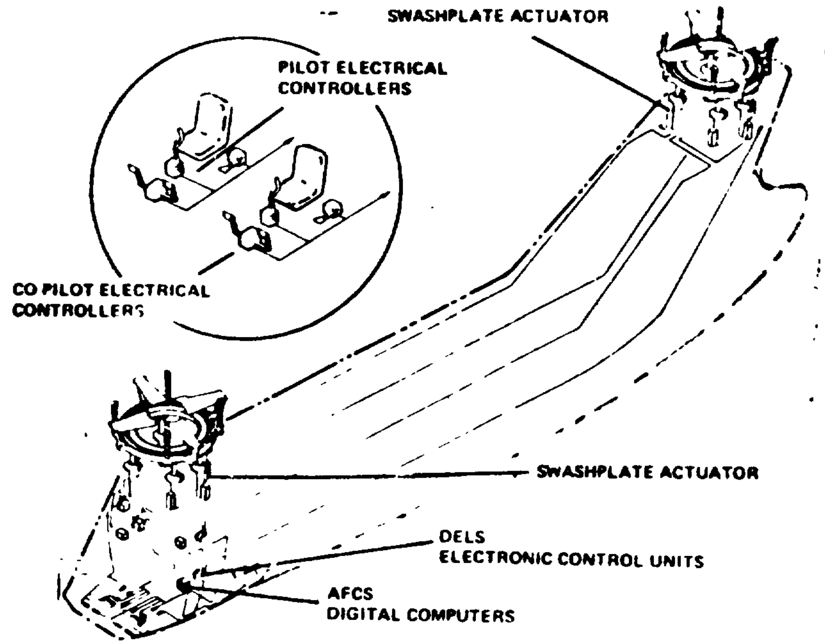
- FLY BY WIRE -
- FUNCTIONS:
  - DIRECT ROTOR CONTROL
  - AUTOMATIC TRIM SYSTEM
  - STABILITY & CONTROL AUGMENTATION SYSTEM
  - NAVIGATIONAL/GUIDANCE

COCKPIT

- LONG./LATERAL STICK
- COLLECTIVE STICK
- DIRECTIONAL PEDALS
- FORCE FEEL/TRIM SYSTEM (PROGRAMMABLE)

ROTOR CONTROLS

- SWASHPLATES
- ACTUATORS - DUAL TRIPLE DRIVER ACTUATORS
- HYDRAULIC POWER SUPPLY



SYSTEMS

- DIRECT ELECTRICAL LINKAGE SYSTEM (DELS)
  - STICK POSITION TRANSDUCERS
  - DELS CONTROL UNIT
  - REDUNDANT WIRING
  - BITE STATUS/CONTROL UNIT
- AUTOMATIC FLIGHT CONTROL SYSTEM (AFCS) ~~TRIPLE REDUNDANT~~
  - SENSORS SIDESLIP/AIRSPEED/ALTITUDE - BARAMETRIC AND RADAR
  - FLIGHT CONTROL COMPUTER
  - SCAS - STABILITY CONTROL AUGMENTATION SYSTEM
- ELECTRICAL POWER SUPPLY/CONTROLS
- ENGINE CONTROL SYSTEM
- NAVIGATIONAL/GUIDANCE COMPUTER
  - AUTO APPROACH TO HOVER

TANDEM ROTOR HELICOPTER

FLIGHT CONTROL SYSTEM BASIC ELEMENTS

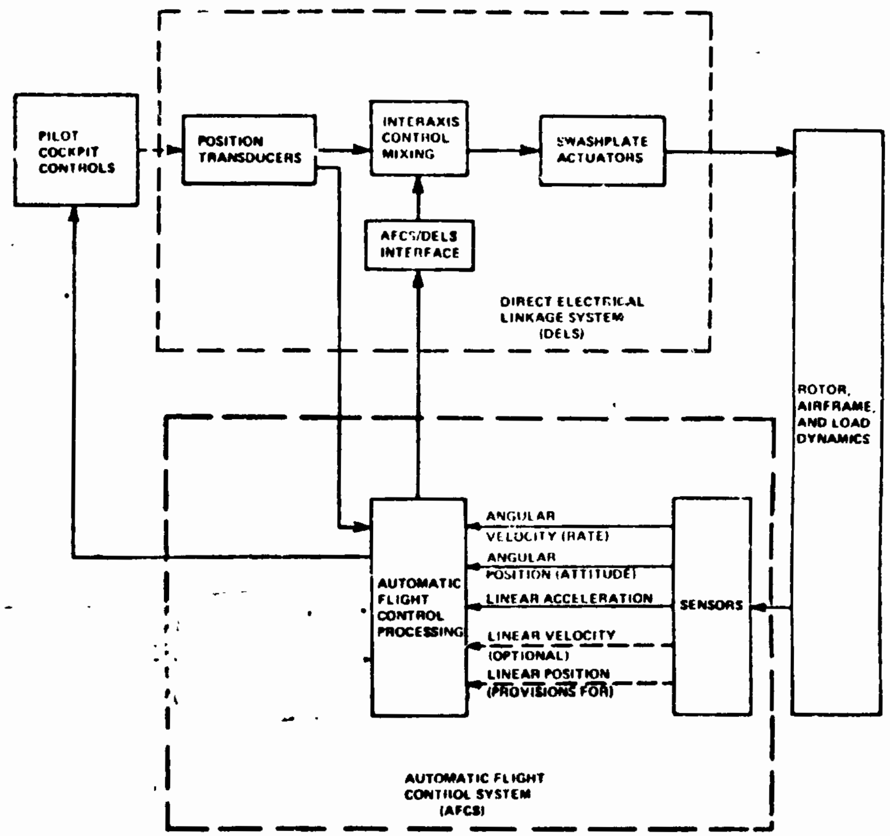


FIGURE 3.43

to be flush with the structure so that no hang up takes place on the structure, thus preventing the fuel cell from being restricted in movement under impact conditions. The impact tests carried out are the human survivable levels of 65 feet per second with a time duration not to exceed .005 seconds. All impact levels above this are considered to be non-survivable and the need to prevent fire is not so great.

SUBSYSTEMS - TILT ROTOR

Some of the subsystem requirements for the design point tilt rotor have been established in performing the design study. The main systems which impact the weight, cost and performance are a) drive system, b) rotor system, c) control system, d) fuel system, and e) nacelle tilt actuation.

Tilt Rotor Transmission

The transmission for the design point aircraft is shown schematically in Figure 3.44. In each nacelle there are two engines which drive through overrunning clutches into the transfer case. The drive system components are listed in Table 3.39 with the design torques and the conditions which size each box.

The transfer case is sized in cruise at NRP 14,000 feet altitude for a total horsepower (2 engines) of 5,824 at cruise RPM. The critical mesh torque in the transfer case is 2,525 foot-pounds at 6,050 RPM.

The output of the transfer case drives into the No. 1 bevel box which is again sized in cruise at NRP 14,000 feet. This bevel has a reduction ratio of 1:2 and transmits 5,800 horsepower at 5,050 RPM to give a critical mesh torque of 6,030 foot-pounds.

The second bevel set is sized for the same flight condition and transmits 5,576 horsepower at an output RPM of 4,590 to give a maximum torque of 6,700 foot- pounds.

The main rotor transmission is an overall 25:1 reduction ratio

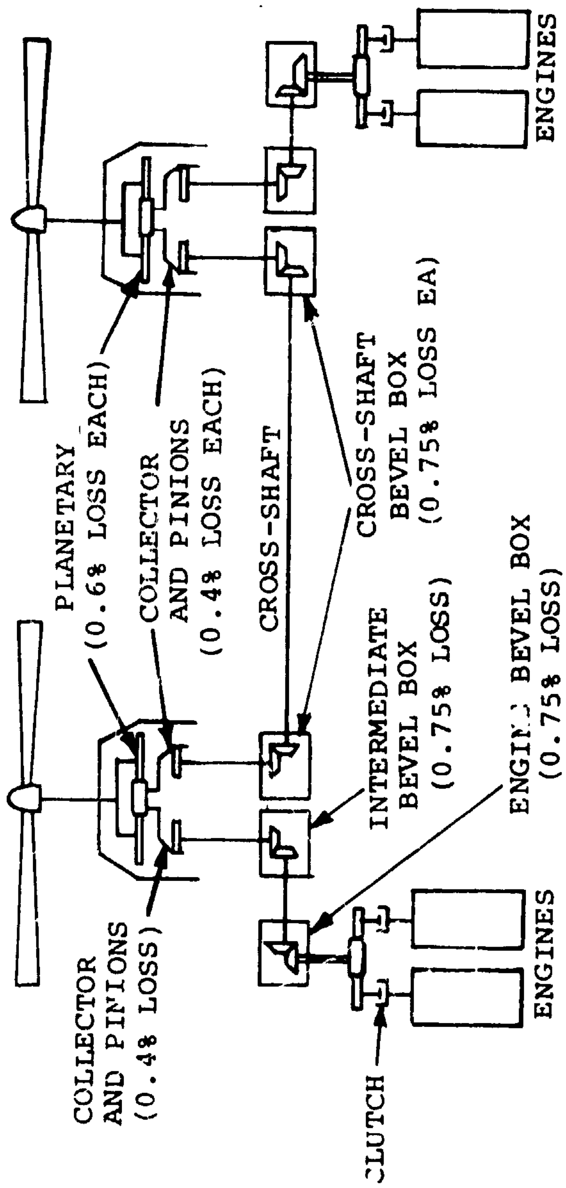


FIGURE 3.44. TRANSMISSION SCHEMATIC.

TILT ROTOR TRANSMISSION SIZING

COMPONENT	INPUT RPM	OUTPUT RPM	INPUT HP	CRITICAL MESH TORQUE FT-LBS	SIZING CONDITION
ENGINE TRANSFER CASE	11860	6050	5824	2525	NRP CRUISE 14,000 FEET
BEVEL BOX NO. 1	6050	5050	5800	6030	NRP CRUISE 14,000 FEET
BEVEL BOX NO. 2	5050	4590	5757	6700	NRP CRUISE 14,000 FEET
ROTOR TRANSMISSION	4590	183.5	5713	164,000	NRP CRUISE 14,000 FEET
CROSS SHAFT BEVEL	4590	4590	4999	5720	HOVER OEI F/W = 1.03 + ROLL CONTROL

TABLE 3.39. TILT ROTOR TRANSMISSION SIZING

to give a rotor shaft RPM of 183.5 and is sized by the cruise torque at NRP (14,000 feet) which is 164,000 foot-pounds. The primary drive train is all sized in cruise at NRP 14,000 feet, however, the system is almost a match at hover sea level standard maximum power.

This bevel has a reduction ratio of 1:2 and transmits 5,800 horsepower at 5,050 RPM to give a critical mesh torque of 6,030 foot-pounds. The second bevel set is sized for the same flight condition and transmits 5,756 horsepower at an output RPM of 4,590 to give a maximum torque of 6,700 foot-pounds.

The main rotor transmission is an overall 25:1 reduction ratio to give a rotor shaft RPM of 183.5 and is sized by the cruise torque at NRP (14,000 feet) which is 164,000 foot- pounds. The primary drive train is all sized in cruise at NRP 14,000 feet, however, the system is almost a match at hover sea level standard day, maximum power.

The main rotor transmission torque at sea level standard is 157,000 foot-pounds at hover RPM. The transmission is rated at 4.5% higher torque than the ground rule requirement of maximum power AEO at sea level standard day.

The cross shaft bevel boxes are sized by the hover OEI requirement at sea level 90 degrees F including a torque split allowance to meet the hover roll control requirement.

The transmission losses used in the analysis are shown in Figure 3.39 and combine to give an overall transmission efficiency of $\eta_T = 0.974$.

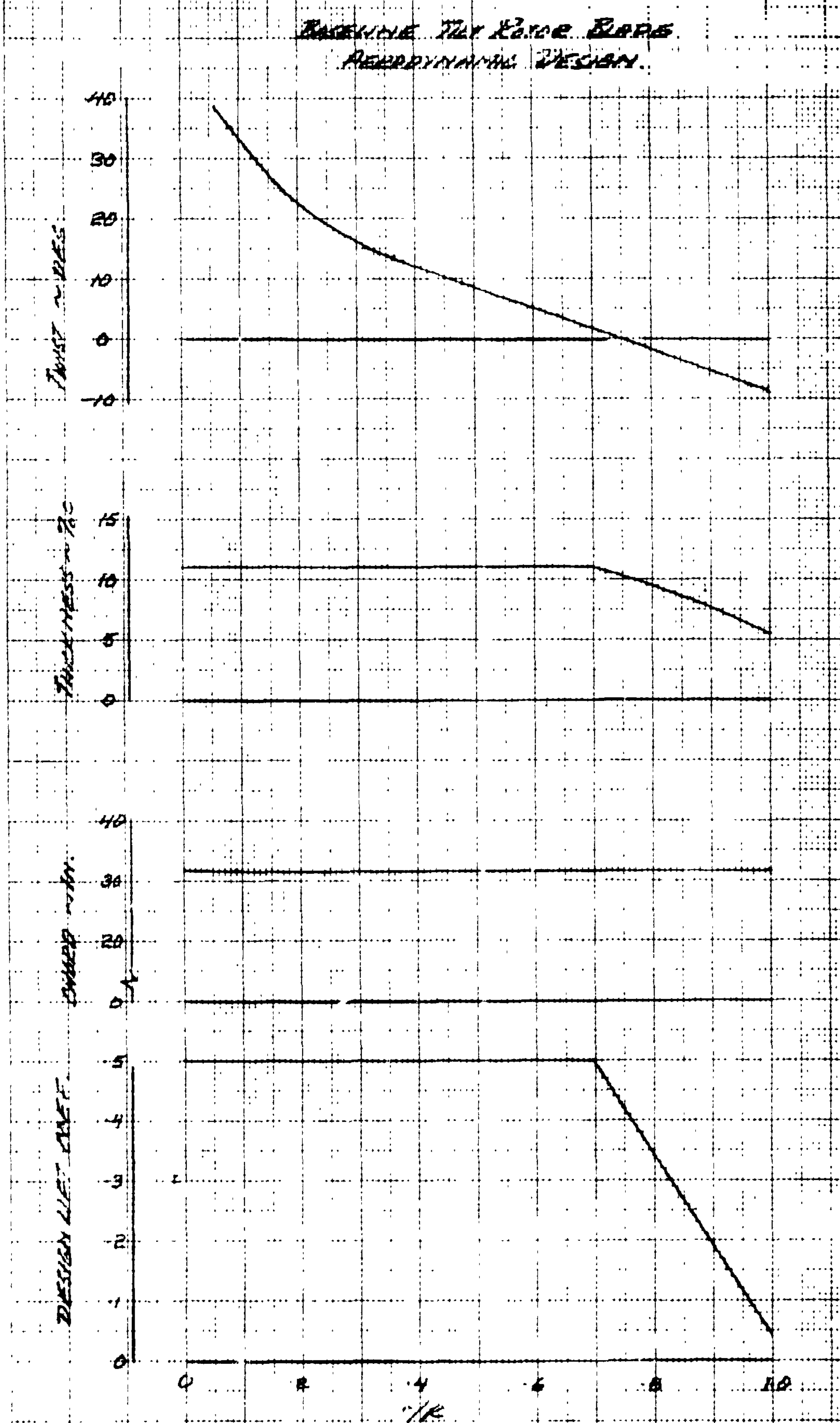


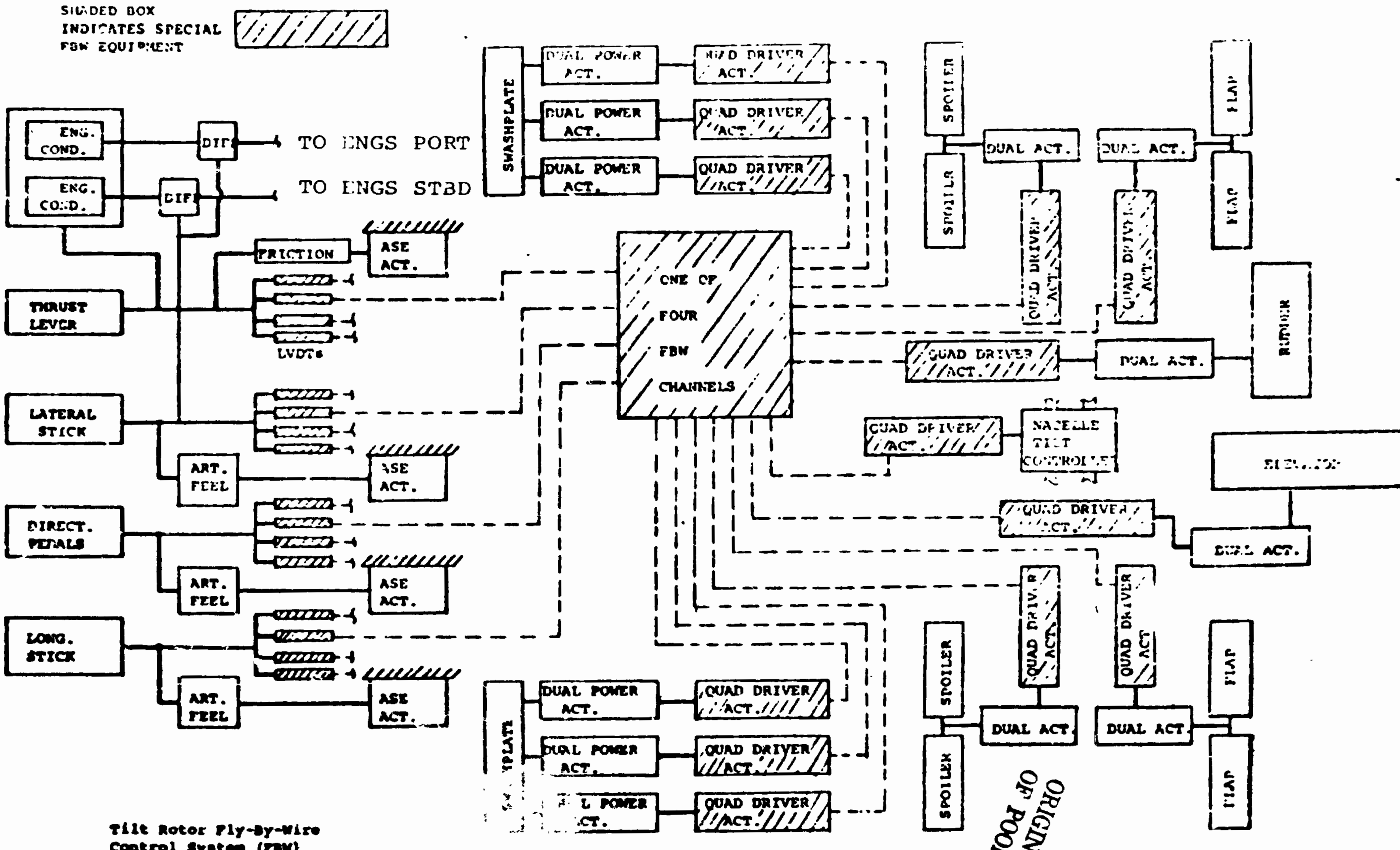
FIGURE 3.45. BASELINE TILT ROTOR - ROTOR GEOMETRY.

Rotor System

The rotor system used in the tilt rotor design is a hingeless soft in-plane rotor. The rotor has three blades and is 56.3 feet in diameter. The rotor solidity is 0.089 giving a blade chord of 31.8 inches. Figure 3.45 shows the characteristics of the blade. The hingeless rotor is attractive for the commercial application since it enables a simpler hub design than the other alternatives (gimballed or articulated). The rotor out-of-plane flapping excursions are low which should make passenger acceptance of the large rotor propulsion system easier. The advantage of design simplicity should favorably impact the maintenance and reliability of the aircraft.

Tilt Rotor - Fly-By-Wire Controls

The tilt rotor control system requires extensive mixing, gain and shaping changes as a function of flight condition and is, therefore, a good candidate for fly-by-wire controls. A block diagram of a possible system is shown in Figure 3.46. Each of the control inputs is converted to electrical signal using linear variable displacement transducers. Four transducers on each control provide inputs to four fly-by -wire channels. Each channel drives one of four driver actuators on each control. The main actuators are hydraulic and are dual actuators which receive command from the four driver actuators. The control logic for failure sensing must be designed to utilize the quadruply redundant system to be "fail operable" with any single failure and "fail safe" with double failure.



Tilt Rotor Fly-By-Wire Control System (FBW)

FIGURE 3.46. FOR FLY-BY-WIRE CONTROL SYSTEM.

In this instance "fail operable" is intended to reflect no degradation of controls in the event of a single failure.

Tail Rotor Fuel System

The fuel tanks are located in the wing. Four self-sealing integral fuel cells are used each with a capacity of 175 gallons. Each tank contains an integral fuel pump and cross feed valving allows for fuel re-distribution in flight. The system is designed for pressure refueling at 300 gallons per minute and incorporates fuel dump values for jettison.

REFERENCES

1. User's Manual for VASCOMP II, The V/STOL Aircraft Sizing and Performance Computer Program.

2. User's Manual for HESCOMP, The Helicopter Sizing and Performance Computer Program.

3. Drag Estimation of V/STOL Aircraft, Boeing Report D8-2194-1, E. A. Gabriel.

4. HLHS Propulsion System Trade Studies. Boeing Report D301-10009-1, May 1971.

4.0 STUDY GUIDELINES AND DESIGN CRITERIA

FOR

CONCEPTUAL DESIGN OF VTOL ROTOR TRANSPORTS

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

August 1973

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4.5.1 Attitude Changes

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4.5.3 Cabin Noise

4.5.4 Ride Qualities

4.5.5 Passenger Cabin Requirements

4.6 Economics

4.1 HANDLING QUALITIES AND FLIGHT SAFETY

4.1.1 Handling Qualities Criteria (low speed powered lift mode)

Except where specific criteria are given, handling qualities shall comply with the recommendations of AGARD-R-577-70. Two levels of criteria are stated; the first is intended for normal operation and the second for operation following any reasonable single failure of the gas generator or control system. Definitions of the two levels are:

Level 1: Flying qualities are as near optimal as possible and the aircraft can be flown by the average commercial pilot.

Level 2: Flying qualities are adequate to continue flight and land. The pilot work load is increased but is still within the capabilities of the average commercial pilot.

4.1.1.1 Attitude Control Power (S.L., ISA + 31°F)

Level 1: At all aircraft weights and at all speeds up to V_{con}, the low speed control power shall be sufficient to satisfy the most critical of the two following sets of conditions.
Conditions (a) -- to be satisfied simultaneously

(1) Trim with the most critical CG position.

(2) In each control channel provide maneuvering control power equal to the most critical of the requirements given in Table 4.1.

Axis	Maximum Angular * Acceleration after a Step Input		Attitude Angle in 1 sec after a Step Input	
	0-40 kts	40-V_{con}	0-40 kn	40-V_{con}
Roll	± 0.6 rad/sec^2	±0.4 rad/sec^2	±10 deg	± 6 deg
Pitch	±0.33 rad/sec^2	±0.3 rad/sec^2	± 6 deg	± 5 deg
Yaw	±0.25 rad/sec^2	±0.2 rad/sec^2	± 5 deg	± 3 deg

TABLE 4.1

*For purposes of the design study these should be construed as control moment/inertia rather than acceleration measured with a control input.

These maneuver control powers are applied so that 100% of the most critical and at least 30% of each of the remaining two need occur simultaneously.

Conditions (b) -- to be satisfied simultaneously

(1) Trim in a 25 kt TAS cross wind with the most critical CG position

(2) In each control channel provide maneuvering control power equal to 50% of the values given in the previous table. Simultaneous control power need be no greater than 100% - 30% - 30%.

Level 2: At all aircraft weights and at any speed up to V_{con}, the low speed control power shall be sufficient to satisfy, simultaneously, the following:

(1) Trim after any reasonable single failure of gas generator or control system.

(2) In each control channel, provide maneuvering control power equal to the most critical of the requirements given in Table 4.2. Simultaneous maneuver control power need be no greater than 100% - 30% - 30%.

Axis	Maximum Angular * Acceleration after a Step Input		Attitude Angle in 1 sec after a Step Input	
	0-40 kn	40 kn - V_{con}	0-40 kn	40 kn-V_{con}
Roll	$\pm$ 0.3 rad/sec^2	$\pm$ 0.2 rad/sec^2	$\pm$ 5 deg	$\pm$ 3 deg
Pitch	$\pm$ 0.2 rad/sec^2	$\pm$ 0.2 rad/sec^2	$\pm$ 3 deg	$\pm$ 3 deg
Yaw	$\pm$ 0.15 rad/sec^2	$\pm$0.15 rad/sec^2	$\pm$ 2 deg	$\pm$ 2 deg

TABLE 4.2

*For purposes of the design study these should be construed as control moment/inertia rather than acceleration measured with a control input.

4.1.1.2 Flight Path Control Power (S.L. to 1000 ft., ISA + 31°F)

4.1.1.2.1 VTOL (0-40 Kt TAS and zero rate of descent)

At all aircraft weights and at the conditions for 50% of the maximum attitude control power specified in para. 1.1.1 it shall be possible to produce the following incremental accelerations for height control.

Level 1:

(a) In free air ± 0.1g

(b) With wheels just clear of the ground - 0.10g + 0.05g.

Level 2:

(a) In free air - 0.1g, + 0.5g

(b) With wheels just clear of the ground - 0.10g, + 0.00g.

It shall also be possible to produce the following horizontal incremental acceleration, but not simultaneously with height control.

Level 1: ±0.15g

Level 2: ±0.10g

At all aircraft weights it shall be possible to produce the following stabilized net vertical force-weight ratios without attitude control inputs.

Level 1: $\frac{F}{W}$ = 1.05 in free air

Level 2: $\frac{F}{W}$ = 1.03 in free air

4.1.1.2.2 VTOL Approach (40 kts to V_{con})

At the maximum landing weight and in 25 kt crosswind, the aircraft shall be capable of making an approach at 2000 FPM rate of descent while simultaneously decelerating at 0.15g along the flight path.

It shall be possible to produce the following incremental normal accelerations in less than 1.5 seconds for flight path tracking when more than 0.1g but less than 0.3g can be developed by aircraft rotation using pitch control.

Level 1: ± 0.1g

Level 2: ± 0.05g

It shall be possible to produce the following incremental normal acceleration in less than 0.5 seconds for flare and touchdown control when more than 0.1g but less than 0.3g can be developed by aircraft rotation using pitch control.

Level 1: ± 0.1g

Level 2: ±0.05g

It shall be possible to produce the following incremental normal acceleration in less than 0.5 seconds for flare and touchdown control when more than 0.1g but less than 0.15g can be developed by aircraft rotation using pitch control.

Level 1: ± 0.1g

Level 2: ± 0.05g

4.1.1.3 VTOL Control System Lags (S.L. to 1000 ft., ISA + 31°F)

The effective time constant (time to 63% of the final value) for attitude control moments and for flight path control forces shall not exceed the levels given in Table 4.3.

	Level 1	Level 2
Attitude Control Moments	0.2 sec	0.3 sec
Flight Path Control Forces	0.3 sec	0.5 sec

TABLE 4.3

The step input is assumed to be applied at the pilots control.

4.1.1.4 Stability (S.L. to 1000 ft., ISA + 31°F)

4.1.1.4.1 Low Speed and Hovering Stability

Level 1: The short period oscillatory modes shall meet the optimum zone specified in Figure 4.1 while maintaining other oscillatory modes damped. Aperiodic modes, if unstable, shall have a time to double amplitude of greater than 20 sec.

Level 2: The short period oscillatory modes meet the Level 2 zone given in Figure 4.1. Other oscillatory modes may be unstable provided their frequency is less than 0.84 rad/sec and their time to double amplitude greater than 12 sec. Aperiodic modes, if unstable, shall have a time to double amplitude of greater than 12 sec.

4.1.1.5 Miscellaneous Requirements

For those aircraft which contain a tail rotor or anti-torque device and the aircraft operating at the most critical combination of airspeed, altitude, gross weight and center of gravity (c.g.), the following requirements shall be met subsequent to the loss of tail rotor thrust (tail rotor intact) or complete separation of the anti-torque tail rotor and tail rotor gearbox from the aircraft in forward flight:

a. The longitudinal c.g. shall not shift forward more than 25% of the total c.g. range.

b. The aircraft shall not pitch uncontrollably.

c. At the speed for minimum power required, the aircraft shall have sufficient directional stability to maintain level flight at a sideslip angle no greater than 20 degrees.

d. It shall be possible to perform a safe landing on a level paved surface without exceeding a sideward drift component of 6 KTAS at sea level standard day conditions.

4.1.2 VTOL Takeoff and Landing Safety Criteria

With the selected takeoff or landing operational procedure, any reasonable single failure of gas generator or control system, together with a simultaneous discrete gust as defined by MIL-F-8785B (ASG),

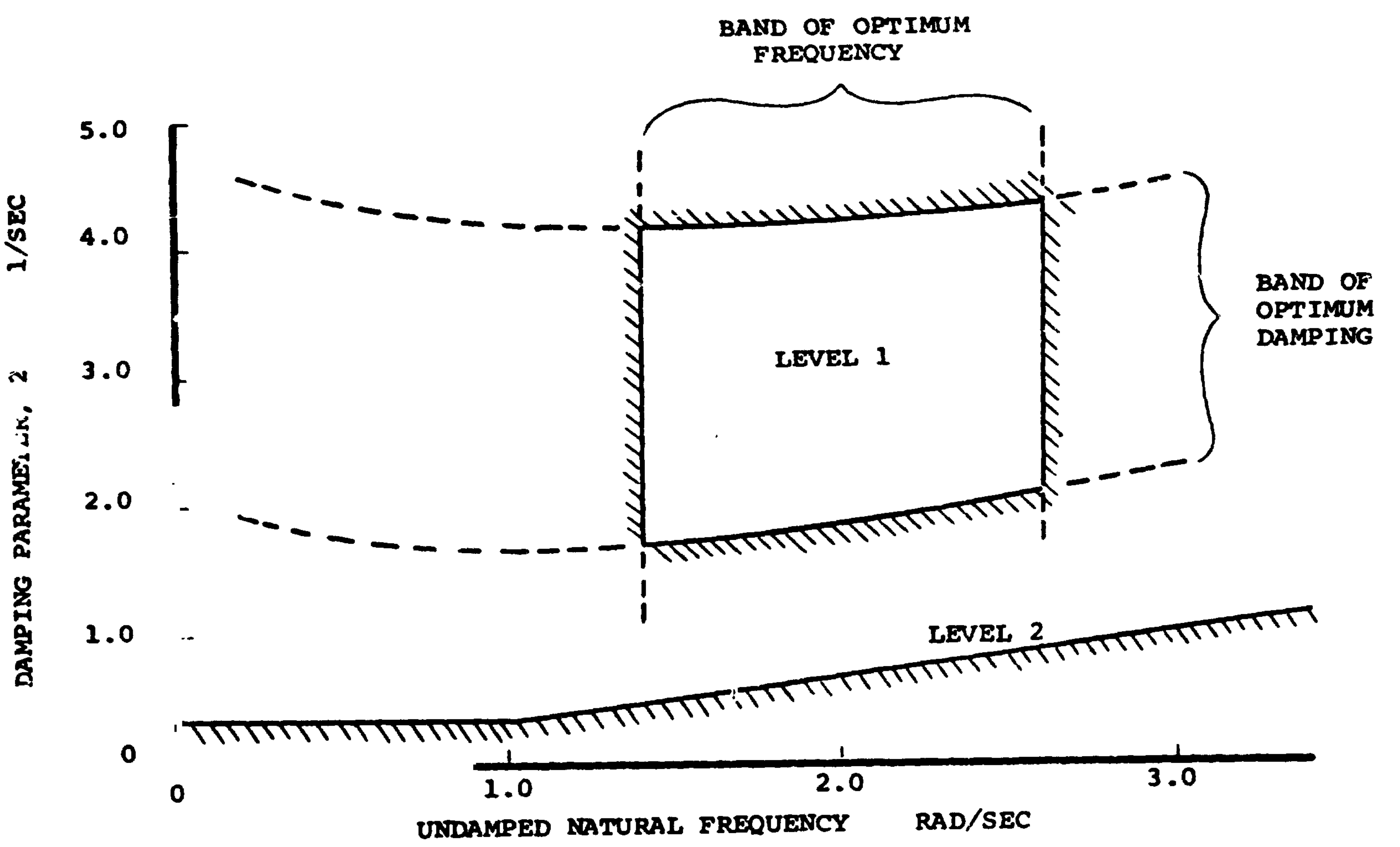


FIGURE 4.1 DYNAMIC STABILITY CRITERIA

about any axis, the aircraft shall be capable of continued sustained flight.

The airfield shall be assumed to be at sea level and the atmosphere ISA + 31°F with a 25 kt cross wind.

The maximum takeoff weight and maximum landing weight shall be the same.

4.1.3 Rolling Takeoff and Landing Safety Criteria

A requirement comparable to that given in Section 4.1.2 shall be satisfied.

Climb out and landing gradients shall be (15:1) and (30:1) with and without a configuration change.

4.1.4 Conversion Requirements

It must be possible to stop and reverse the conversion procedure quickly and safely without undue complicated operation of the powered lift controls.

4.1.5 Fuel Reserves

	VTOL
Holding at 5000 ft. and most economical speed	20 min.
Flight to alternate airport	50 nm

These reserves are to be calculated on the basis that the flight to the alternate airport shall be at the most economic fuel consumption condition, and the hold at 5000 ft. is on the descent at the alternate airport.

4.1.6 System Failures

Upon any single reasonable failure of the propulsion or the control systems, while at maximum VTOL design gross weight, the aircraft shall be capable of continuing sustained flight. This includes, upon an engine failure, sustained hovering flight out of ground effect, sea level 90°F day, at maximum design takeoff gross weight. An emergency rating of 1.09 times the engine takeoff power rating is permitted on the operative engines.

4.2 PERFORMANCE

4.2.1 Aircraft Operating Capability

Maximum rate of descent for gear design shall be 480 ft. per minute.

Airports are at sea level with an ambient air temperature of 90°F.

4.2.2 Payload - Range

Each passenger will be assumed to have a weight of 180 lb. (160 lb. per passenger and 20 lb. of non-revenue baggage). No revenue cargo is assumed. Nonstop range is standard atmosphere still air at maximum payload at normal cruise airspeed and without using reserve fuel shall be as dictated in the Statement of Work.

4.2.3 Cruise Airspeed and Altitude

Cruise speed shall be as specified in the Statement of Work. Cruise altitude shall be such that the cruise distance is at least one-half of the total stage length.

4.2.4 Mission Profile

The mission profile is shown in Figure 4.2. Maximum airspeed shall not exceed 250 kt IAS below 10,000 ft. altitude. For pressurized operation, climb rates shall be such that the rate of cabin pressure altitude change does not exceed 500 fpm and descent rates shall be such that the rate of cabin pressure altitude change does not exceed 300 fpm.

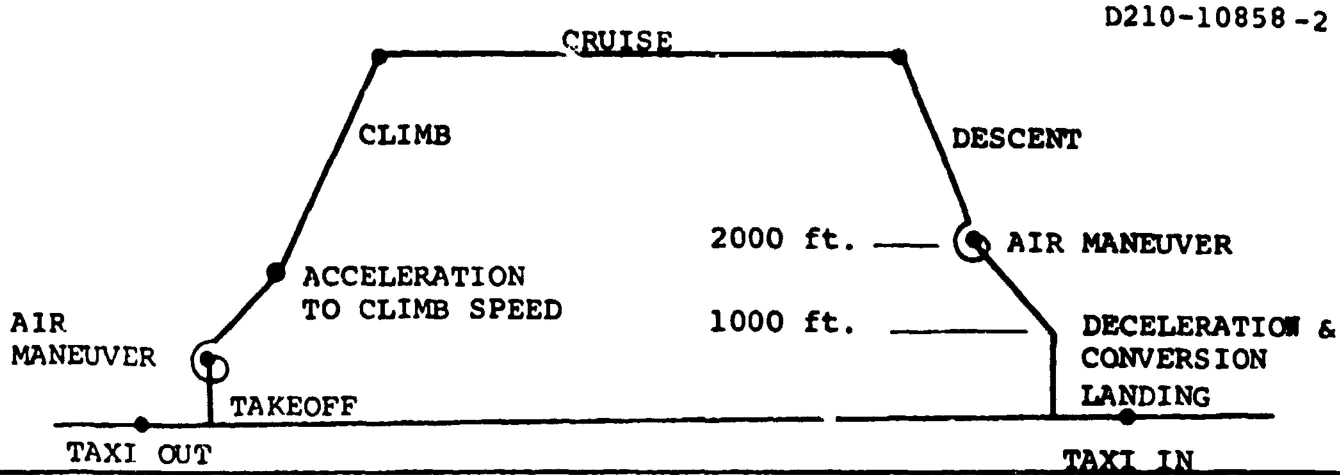
4.3 NOISE LEVELS

As specified in the Statement of Work.

4.4 GENERAL DESIGN GUIDELINES

4.4.1 Number of Crew and Cabin Attendants

Accommodation and equipment shall be provided for a flight crew of two and for one cabin attendant per 50 passengers. In addition, some provision shall be made on the flight deck for an occasional flight observer. Each crewman plus gear weighs 190 pounds, and each cabin attendant plus gear weighs 140 pounds.



SEGMENT	TIME VTOL	DISTANCE VTOL	REMARKS
Taxi Out	1 min.	0	
Takeoff, Transition & Conversion to Conventional Flight	0.5 min.	0	
Air Maneuver (Origin)	0.5 min.	0	
Acceleration to Climb Speed	As Calculated		
Climb	As Calculated		At opti[illegible]limb Spd
Cruise	As Calculated		At Cons[illegible]t Integral 1000 ft. Altitudes(No Enroute Altitude Chan[illegible]
Descent to 2000 ft.	As Calculated		5000 fpm maximum rate of Descent
Air Maneuver at 2000 ft. (destination)	1.5 min.	0	
Decelerating Approach and Conversion to Powered Lift Flight 2000 ft. to 1000 ft.	As Calculated	0	1000 fpm maximum Rate of Descent
Transition and landing from 1000 ft. to Touchdown	As Calculated	0	1000 fpm maximum Rate of Descent Down to 35 ft. 600 fpm Maximum Rate of Descent Below 35 ft
Taxi In	1 min.	0	

FIGURE 4.2 V/STOL MISSION PROFILE DEFINITION

4.4.2 Aircraft Design Life

Aircraft design life shall be 40,000 hours.

4.4.3 Baggage Hold

1.5 cubic feet per passenger shall be provided in locked overhead compartment, under seat, or near door rack for carry on luggage. 2.5 cubic feet shall be provided for checked luggage.

4.4.4 Auxiliary Power Unit (APU)

The aircraft shall be equipped with an APU to meet the needs of starting, ground air conditioning and heating.

4.4.5 Aircraft Materials

The aircraft designs are to be based on a 1985 operational time period. The contractor shall assume that the airframe structural weight will be reduced approximately 25% by the use of composite materials.

4.4.6 All Weather Capability

It is to be assumed that by 1985, a system to permit all weather operation will have been established and that the V/STOL short-haul transport system will use it.

4.4.7 C.G. Limits

The allowable center of gravity travel shall be a payload shift of ± 5% of the passenger cabin length.

4.4.8 Cruise Stability

The aircraft as configured for cruise flight shall be statically stable with a stability margin of 0.05 at the critical center of gravity without stability augmentation.

4.4.9 Standard Weight Items

The weights shall be as provided in Table 4.4.

TABLE 4.4

ITEM	WEIGHT
WHEELS, TIRES, AND BRAKES	COMPANY OPTIMUM
INSTRUMENTS (Flight and Navigation) ELECTRICAL (Excluding Generating Equipment) ELECTRONICS (Communication, Flight, and Navigation) AUXILIARY POWER UNIT INSTALLATION	1200 lbs.
SEATS AND BELTS	
PASSENGER: DOUBLE	16 lb/passenger
TRIPLE	16 lb/passenger
CREW SEATS: CABIN CREW	16 lb/crew member
FLIGHT CREW	40 lb/crew member
LAVATORY	300 lb/unit
BEVERAGE ONLY	200 lb/total
AIR STAIR	400 lb

4.4.10 Fly-by-wire Control Systems

Fly-by-wire control systems are permitted. Control configured vehicles (CCV), such as tailless tilt rotor configuration, are not permitted.

4.4.11 Gearboxes

The rotor gearboxes shall be designed for the maximum rated engine power and torque under sea level standard day conditions.

4.4.12 Engines

Rubberized versions of existing engine designs are permitted, as appropriate for commercial service in 1985. The engine specific weight shall be pounds per shaft horsepower, and as a guideline example fuel consumption values are

4.5 PASSENGER COMFORT

This section is concerned with criteria related to passenger comfort rather than passenger safety. These criteria usually impose more severe design restrictions than do the safety criteria. Because of their possible impact on economics, the penalties they incur should be carefully considered during the course of the study. As a goal, the aircraft shall have a level of comfort equal to that provided in the tourist section of commercial jet airliners. The maximum vibration level should at least no exceed ± .05g at frequencies up to 20 Hz.

4.5.1 Attitude Changes in Normal Operation

The fuselage deck attitude relative to the horizontal shall not exceed +20 degrees or be less than -10 degrees.

4.5.2 Force Changes in Normal Operation

The maximum force changes acting on the passenger, due to a normal maneuver, shall not exceed

± 0.1g laterally

± 0.4g longitudinally

± 0.4g - 0.2g vertically

These force changes are measured relative to a set of axes fixed in the passenger seat such that, in level, unaccelerated flight, the gravitational vector is along the vertical axis..

4.5.3 Cabin Noise

The sound level in the flight crew and passenger cabins shall not exceed speech interference levels, namely 75 db for takeoff and 70 db for cruise. The three preferred octave bands for this basis shall have mid-range frequencies of 500, 1000, and 2000 Hz.

4.5.4 Ride Qualities in Turbulence

Short haul V/STOL transport missions, particularly those of less than about 100 sm stage length, are most economically operated at altitudes which are low compared with medium and long range missions operated by conventional jet transports.

Since the air turbulence rms level increases rapidly below an altitude of 30,000 ft. it is clear that acceptable ride qualities are going to be more difficult to attain in short haul V/STOL transports. It is even possible that ride qualities considerations may have a primary influence in both aircraft design and operating techniques.

In Figure 4.3 an approximate boundary condition for acceptable ride qualities is given as a function of the gust sensitivity parameter, a_n/U_{de}, versus altitude. It is not required that initial aircraft conceptual designs meet these ride qualities criteria. It will be expected that final conceptual designs will be evaluated to determine their gust sensitivity. For this purpose each final conceptual design will be evaluated at cruise altitude and for cruise at 10,000 feet and the respective gust sensitivity value will be compared with this ride qualities boundary. Should the final design fail to meet this criteria the contractor shall present the weight penalty which would occur if the aircraft meet this criteria.
(a_n = incremental normal acceleration, g units;
U_{de} = derived gust velocity, ft/sec).

4.5.5 Passenger Cabin Requirements

Aisle width - 19 inches

Seat pitch - 34 inches

Seat width - 21 inches (overall)

Dual Aisle

Cabin baggage

Overhead - carry-on soft-type only
Under seat - room for attache case (9" x 16" x 23")

Floor mounted coat rack (capacity for 80% of passengers)

Beverage service

Lavoratories - one per 50 passengers

Magazine racks - one per 50 passengers (maximum of two)

Folding table - one per seat

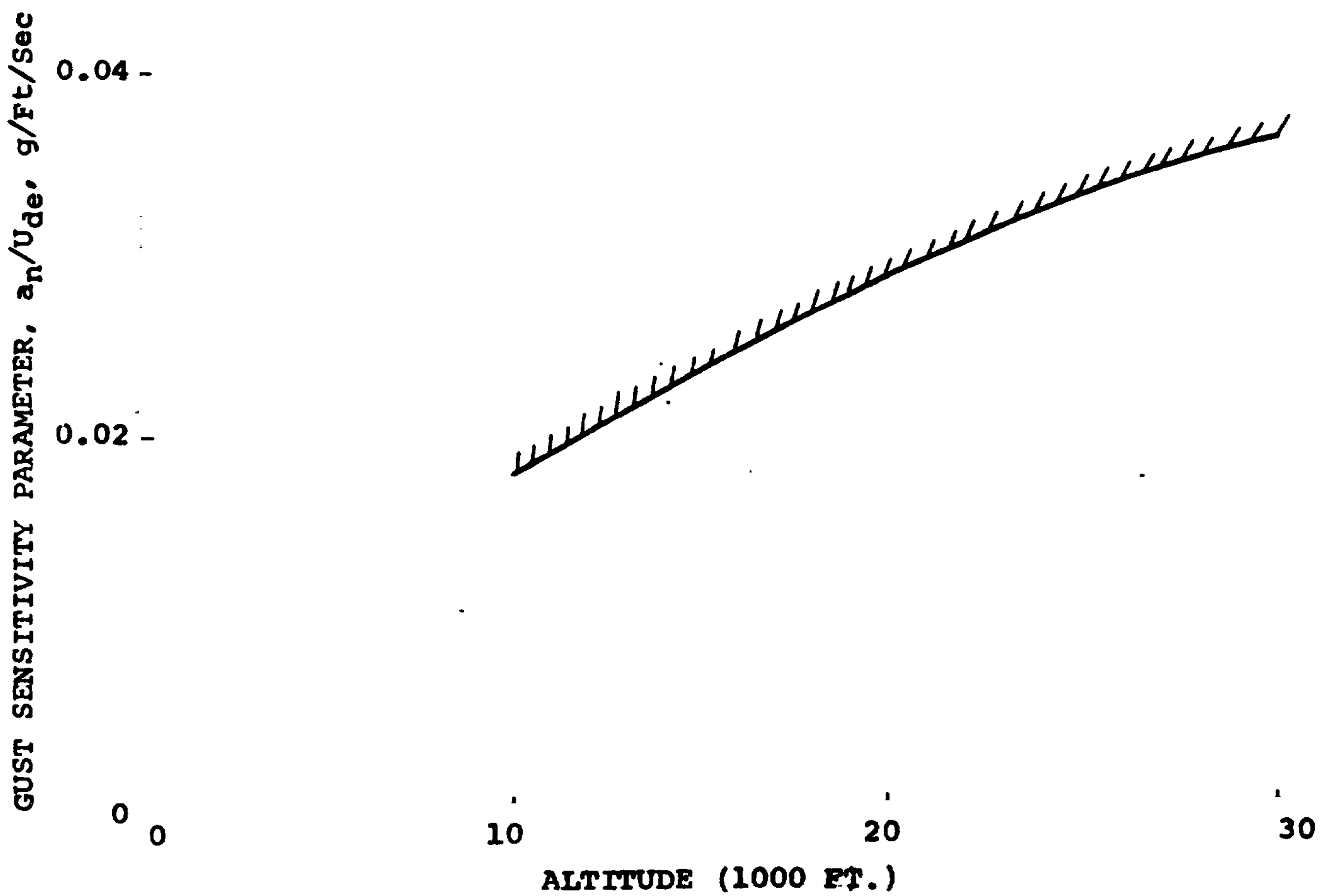


FIGURE 4.3 PASSENGER RIDE DESIGN CRITERION

Air vent - one per passenger

Two entrance doors - one with self-contained means of egress

Ticket center

Attendants seats

4.6 ECONOMICS

To be provided by NASA.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA 94035

REPLY TO ATTN OF FPV:237-2

February 14, 1974

Boeing Vertol Company
Attn: Mr. J. Magee
P.O. Box 16858
Philadelphia, PA 19142

Reference: Contract NAS2-8048

In accordance with the guideline review coordination meeting held at the Ames Research Center on February 11 and 12, 1974, the changes made to Appendix A of the contract Statement of Work are enclosed.

Woodrow L. Cook
Chief, V/STOL Projects Office

Reference Contract NAS2-8048

Section 1.1

A time history of aircraft motion to a step control input about each axis is to be furnished. These time histories are required only for the final design.

Section 1.2

In place of MIL-F-8785B for gust definition, contractor shall consider a sharp-edge gust of 15 ft amplitude, 5 sec duration, to be considered horizontal, lateral and longitudinal only.

Section 4.7

The allowable minimum center of gravity travel shall be a payload shift of + 5% of passenger cabin length, however, the limits are left to the contractor to provide the best compromise between design, control margin, and loadability.

Section 4.8

The aircraft as configured for cruise flight shall be designed to have positive maneuver stability at the critical center of gravity, without stability augmentation.

Section 4.9

The weight of 1200 pounds for standard weight items shall be considered uninstalled weight.

Section 4.11

The main gear box shall be flat rated to hover power at sea level, 90°F at takeoff gross weight. Input sections to main box to be rated at maximum engine output horsepower.

Section 4.12

In the sizing of the engines the contractor shall use a SFC of .42 lb fuel per hour/horsepower and an engine weight of .15 lb/shaft horsepower.